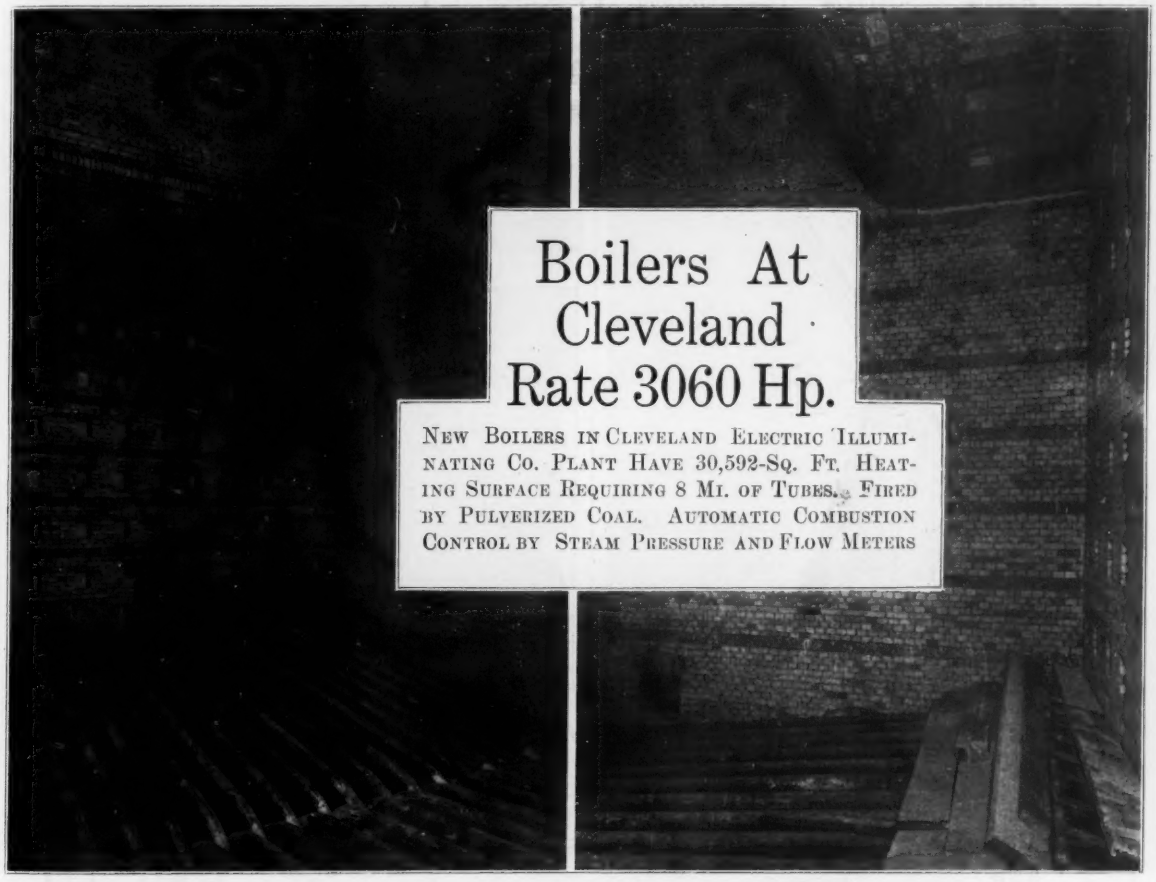
POWER PLANT ENGINEERING

Trade Mark, Reg. U. S. Pat. Office

VOL. XXVIII CHICAGO, MAY 15, 1924 No. 10



Boilers At Cleveland Rate 3060 Hp.

NEW BOILERS IN CLEVELAND ELECTRIC ILLUMINATING CO. PLANT HAVE 30,592-SQ. FT. HEATING SURFACE REQUIRING 8 MI. OF TUBES. FIRED BY PULVERIZED COAL. AUTOMATIC COMBUSTION CONTROL BY STEAM PRESSURE AND FLOW METERS

POSSIBLY NO BETTER way of visualizing the size of the new 3060-hp. boilers in the plant of the Cleveland Electric Illuminating Co. could be presented than to state that 8 mi. of 3¼-in. O. D. No. 8 gage water tubes were used in securing the 30,592 sq. ft. of water heating surface. If this is not sufficient, then a statement that there are 6 steam drums, 32 ft. 8 in. long and 42 in. in diameter; that the units are 55 ft. 5 in. high from the ash gates to the center of the steam drums; that the combustion chamber volume is 29,150 cu. ft. or that nearly 2 mi. of tubing was used in the economizers, might complete the size picture of these giant units.

Size alone is not the only interesting feature of this extension to the Lake Shore Station for the details of the hollow wall furnace construction, the general arrangements for the burning of pulverized coal and the new Bailey system of combustion control are all points which mark the advance of modern power plant construction.

Although this station in reality is an extension of the Lake Shore station the design problem has been approached from an entirely different viewpoint than it was when the older sections were laid out. In other words, the new section is a complete entity with all the individuality and design features which it would have had were it entirely separated from the old station.

In the two existing sections of the station there are in service 86 boilers varying in rated capacity from 472 to 686 hp., with a total rated capacity of 53,866 hp. In the new section four boilers will give an additional rating of 12,240 hp. or approximately one-fourth of the total rating represented by the 86 old units. Under extreme conditions of load it is probable that the new boilers can develop 50,000 hp. while a forced rating of 100,000 hp. is about all that can be expected from the old units. It is said that with its total rating of 66,106 b.hp., the Lake Shore station has the largest number of boiler horsepower under one roof, of any plant in the world.

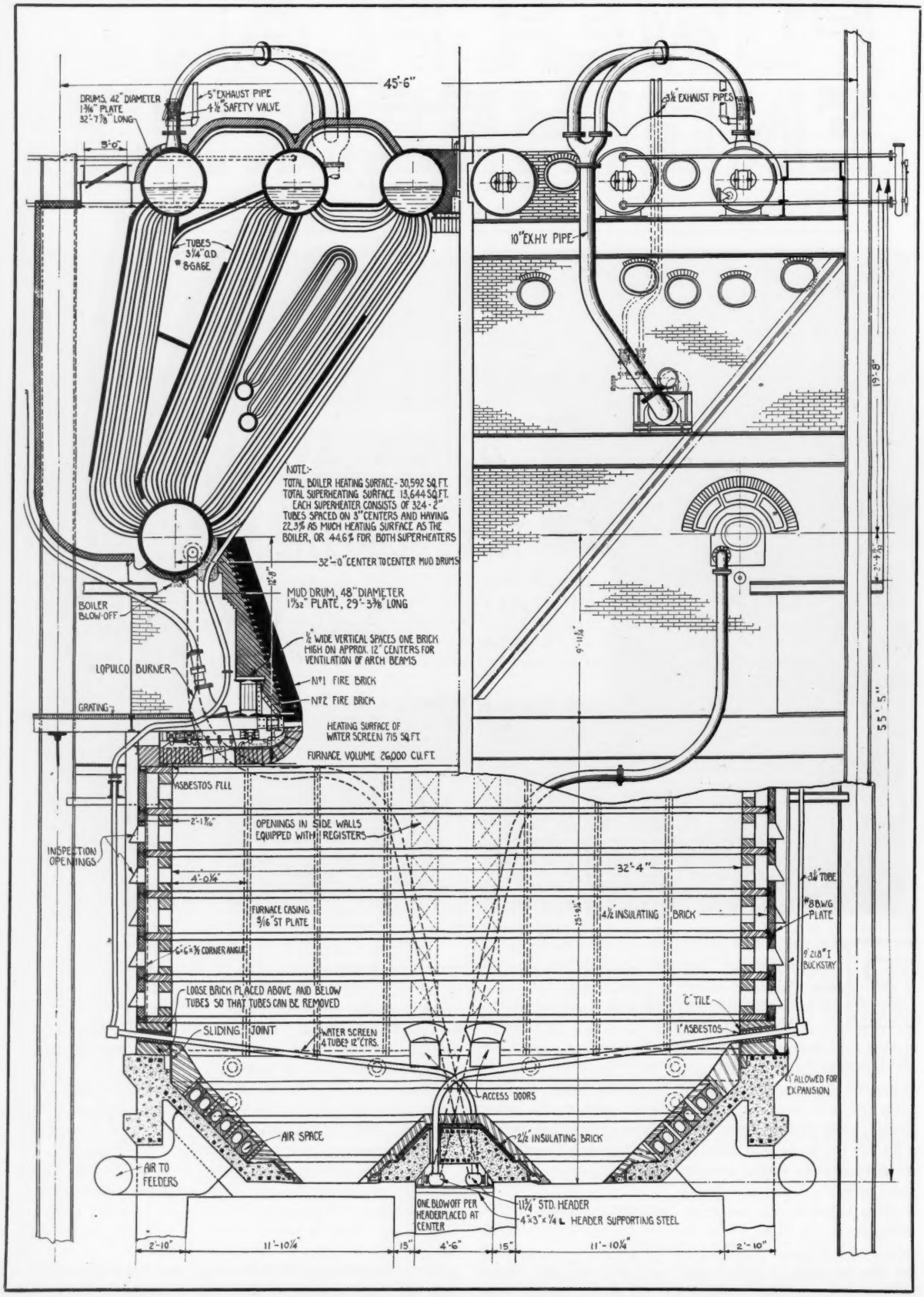


FIG. 1. FURNACE VOLUME IS 29,150 CU. FT. IN THIS 3060-HP. BOILER

Chain grate stokers are used for all boilers in the old section while the four new boilers are fired with pulverized coal. These units are installed in an extension to the No. 2 section. Each boiler unit consists of two Stirling class 13 boilers, twin setting, 55 tubes wide, placed over a single furnace and delivering steam to a common header. The operating pressure is 275 lb. gage with superheat of 236 deg. F. at 200 per cent of rating, or a final steam temperature of 650 deg. F.

It is contemplated that these four boilers will operate normally at 225 per cent of rating, and during peak hours in the late fall and early winter months at 300 per cent rating.

Figure 1 shows a partial section and a partial exterior view of one of these boilers which gives an idea of the general arrangement of the twin setting. The six steam drums are built up of $1\frac{3}{16}$-in. steel plate with butt joints. There are two mud drums 29 ft. $3\frac{3}{8}$ in. long by 48 in. diameter, built of $1\frac{1}{2}$-in. plate. The water tubes which connect these drums have an average length of 19 ft. and are $3\frac{1}{4}$ in. outside diameter, No. 8 gage steel.

As will be noted from Fig. 1 there are four passes, with the baffles located before No. 1, 6, 11, and 15 tubes counting from the front of the setting.

Each half of the boiler has its own superheater of the Babcock & Wilcox convection type, located in the first pass. These superheaters each have a heating surface equivalent to 22.3 per cent of the boiler heating surface or a total of 44.6 per cent which is equivalent to 13,644 sq. ft.

There are two Foster economizers for each boiler unit, each of which is made up of 234—16-ft. steel tubes giving a total heating surface of 22,464 sq. ft. In other words, the economizer surface is 73 per cent of the boiler heating surface or 7.3 sq. ft. of surface per rated boiler horsepower.

With an entering feed water temperature of 190 deg. F. these economizers will deliver water at 280 deg. F. at 200 per cent rating; the gas temperature entering is 530 deg. F. with an exit temperature of 260 deg. F. or a temperature difference of 270 deg. F.

In order to overcome the draft loss through the boiler setting and economizer and also for the purposes of regulating draft pressure an induced draft fan is installed in each flue before the flues join the main flue which leads to the stack. These induced draft fans are of the Sturtevant cinder vane type, 10 ft. in diameter, with a capacity of 95,000 cu.-ft.-min. and are driven by 150-hp. General Electric brush shifting alternating current motors. These motors permit a wide variation in speed with a result that the induced draft fans are tied in with the combustion control scheme as outlined in the latter part of this article.

Referring again to Fig. 1, it will be noted that the design of the furnace shows a number of interesting features. The wall itself consists of a 9-in. fire brick inner wall, an air space $10\frac{1}{2}$ in. wide, $4\frac{1}{2}$ in. of insulating brick and then the steel casing. The inner wall, made up of standard size first quality fire brick is held in place by courses of 18 by 9 by $4\frac{1}{2}$-in. holding tiles spaced at inter-

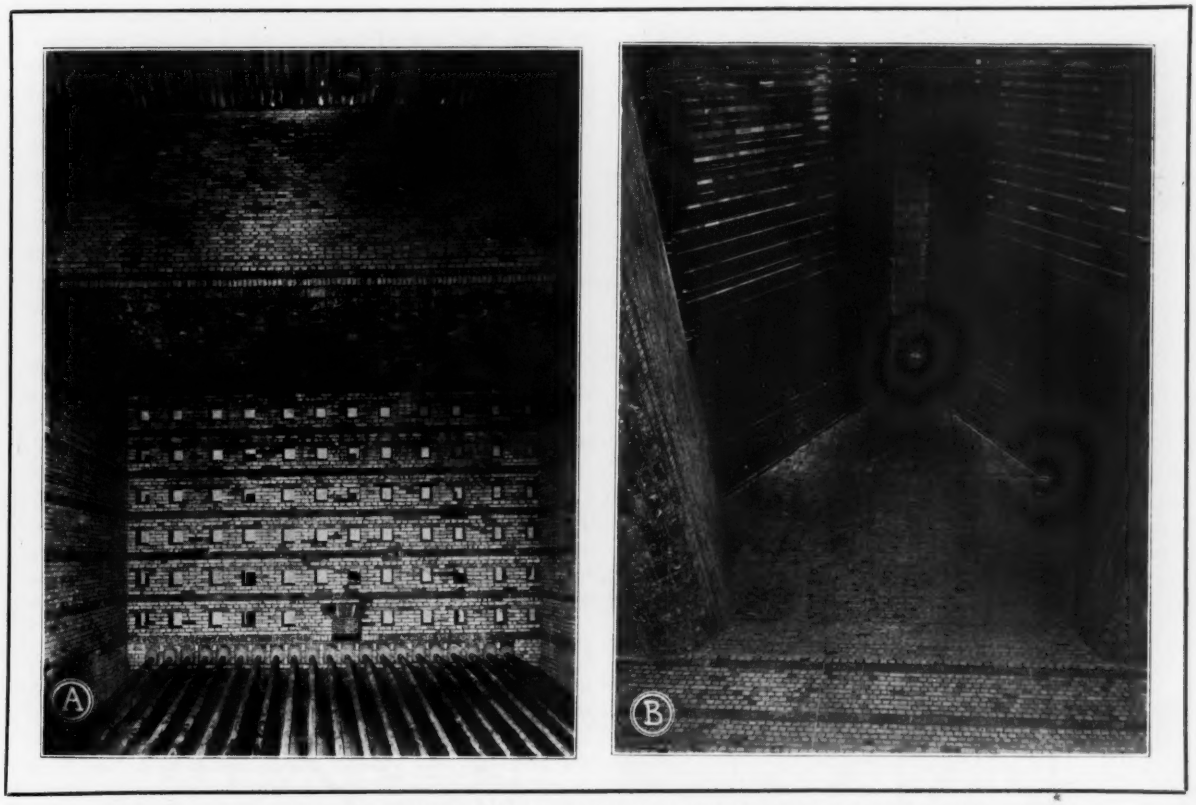


FIG. 2. TILE COURSES TIE INNER AND OUTER WALL TOGETHER IN THE HOLLOW WALL SETTING

A. Looking toward the front wall of the setting. The rectangular openings are for the admission of secondary air which feeds through ducts in the hollow wall. These ducts are between the tile courses, which show as a darker color. The openings in the arch are for the burners. B. Looking up towards the water tubes of the boiler. The baffles are plainly visible.

vals of 10 courses. The holding tiles are anchored to the furnace casing by means of lugs or clips that hook over 5-in. H beams bolted to the casing.

These large holding tiles form six horizontal air passages 10½ by 23½ in. entirely surrounding the furnace. The air enters these passages through regulating dampers in the side walls, circulates through the passages around to the front wall and enters the furnace through a series of ports in the inner lining of the front walls. Those ports are so spaced that the air currents sweep across both sides of the flame. The air is preheated about 150 deg. F. before entering the furnace. Natural draft is sufficient to overcome resistance through the hollow wall ducts, a draft of 0.2 to 0.3 in. at the top of the furnace being all that is required. The amount of air entering the furnace is adjusted by means of the side wall dampers.

Another interesting feature of this installation is the water screen. It consists of 4-in. furnace tubes spaced on 12-in. centers, with 42 tubes in each furnace. These tubes are tied into the boiler circulation through headers and connecting pipes as shown in the accompanying cross section of the furnace.

Primarily the function of the water screen is the prevention of slag. Particles of ash that settle out of the furnace and drop between the water screen tubes are kept below their fusing temperature and accumulate in the ash pit in the form of coarse sand and small fused beads.

This water screen adds heat-absorbing surface to the boiler, which amounts to an effective heating surface of 715 sq. ft. Since the tubes are exposed to direct radiation from all parts of the furnace they absorb heat at a more rapid rate than the first row of boiler tubes.

Although the total combustion space is 29,150 cu. ft., the effective combustion space above the water screen amounts to 26,000 cu. ft. In addition to this large volume, the conformation of the furnace is such that an extremely long flame travel is secured. The path of the flame has an average length of 55 ft., which allows a sufficient time interval to insure complete combustion of gases before they strike the first row of tubes.

It is interesting to note that the furnace volume in proportion to the water heating surface is even larger than for the Cahokia installation which was described in the April 1 issue. At Cahokia the boilers are rated at 1801

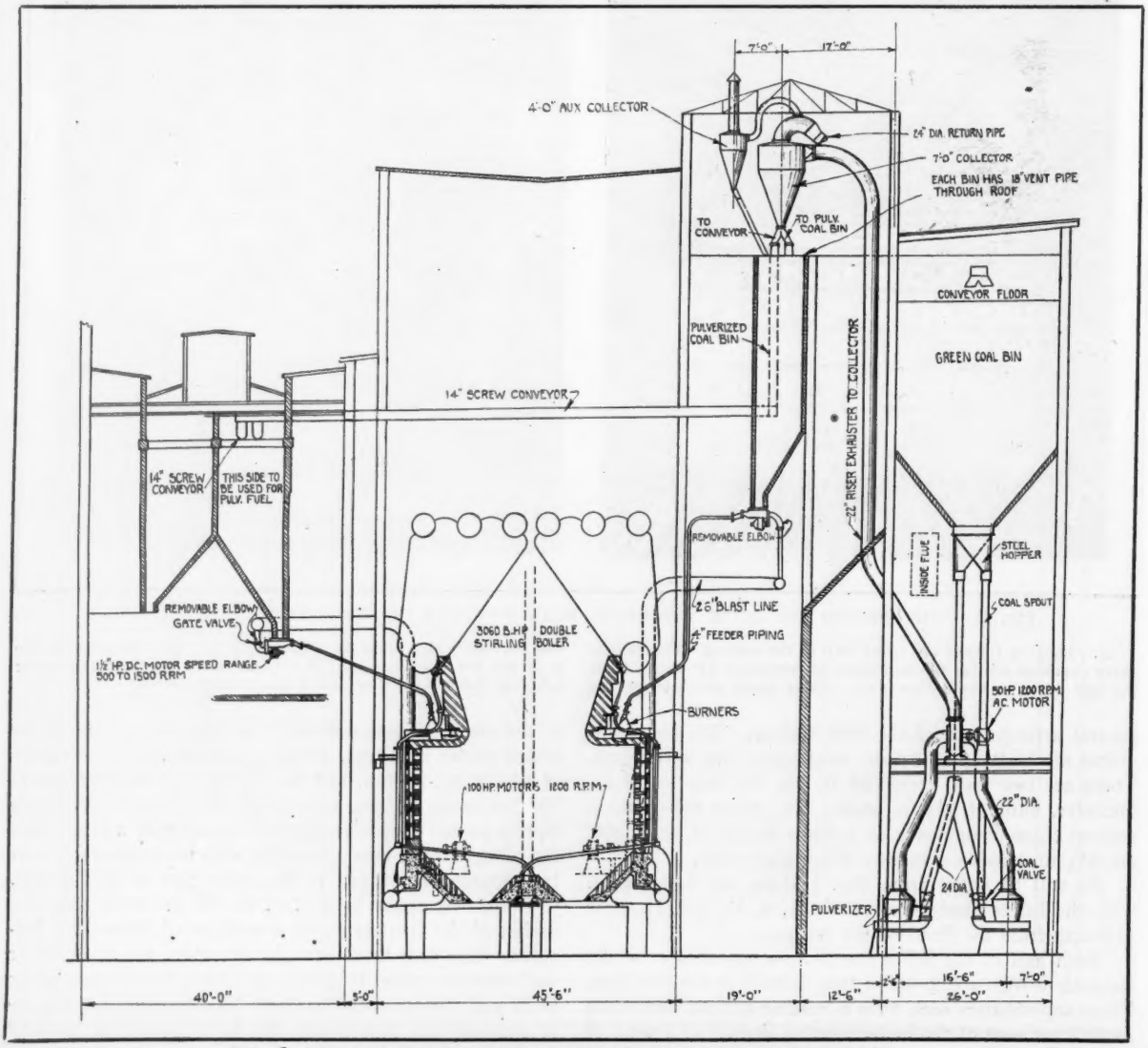


FIG. 3. ARRANGEMENT OF THE PULVERIZED COAL PREPARATION PLANT

hp. with 18,010 sq. ft. of heating surface with an effective volume of 11,440 cu. ft. This gives a ratio of 0.635 cu. ft. of volume for each square foot of heating surface. In the Cleveland installation this ratio is 0.85 figured on a basis of effective volume or 0.95 on a basis of total volume.

On a basis of rated horsepower the Cleveland furnaces figure 8.5 cu. ft. per b.hp. while at Cahokia this is 6.34. At the River Rouge plant the furnace volume per rated horsepower is 4.9 cu. ft. and at the Lakeside Station, Milwaukee, it is 4.86.

Burners Placed at an Angle

Another point of difference between this furnace design and the one at Cahokia is the arrangement of the burners and the front furnace wall. In the Cleveland installation the axis of the burner is inclined about 10 deg. from the vertical so that the flame is directed away from the front walls and toward the center of the furnace. Consequently there is no possibility of flame impingement and erosion of brickwork. At Cahokia the wall at the burners is inclined back and the burners are set vertically. This also produces the same effective result.

It will be noted from Fig. 3 that the pulverized fuel bins extend along each side of the row of four boilers a distance of 175 ft. Each one is subdivided into eight sections which may be readily emptied when the particular unit served is taken off the line.

Four screw feeders are located at the bottom of each bin section, eight of these serving one side of each furnace, or sixteen per furnace. A cast-iron screw, about 4 ft. long, is located at the bottom of each feeder body, driven by a 1½-hp. adjustable speed motor of 525 to 1575 r.p.m. Pinion gears reduce the screw speed to 120 r.p.m. maximum. The rotating screw carries the powdered coal to a small mixing chamber at the end of the screw where it is thoroughly mixed with a small quantity of air under moderate pressure just before it enters a 4-in. pipe line leading to a burner, of which there are eight on each side of the furnace.

Each feeder and burner has a capacity of 2200 lb. per hr. or a total of 17½ T. per boiler. The burner has a flat flared nozzle, the plane of which is at right angles to the front wall although, as previously mentioned, the axis of the burner is pitched 10 deg. toward the center of the furnace. The nozzle is placed in a body or housing which forms an air passage surround the fuel nozzle and is properly dampered, so that the cast iron structure is kept cool against radiation back from the furnace, and ignition controlled at the burner nozzle.

Air to Burners Preheated

About 20 per cent of the air required for combustion is forced in by pressure fans through the burner. This air, as will be noted from Fig. 1 and Fig. 3, is first drawn through the hollow walls of the ash hoppers and then forced up to the feeders. In this way the primary air for combustion is preheated and advantage is taken of the cooling effect on the ash hoppers. The position and shape of the nozzle through which the fuel is introduced into the furnace, insure maximum surface of flame exposed to aerification. As the flame is projected downward it encounters cross currents of air induced by natural draft through a series of openings in the front walls, so spaced that they direct the air along both sides of the flame as it sweeps downward into the furnace.

FIG. 4. AIR CURRENTS CARRY THE PULVERIZED COAL TO THESE COLLECTORS, 110 FT. ABOVE THE MILLS

Figure 3 gives an idea of the general arrangement of the coal preparation plant for supplying the pulverized fuel. After being crushed, the green fuel is distributed to a continuous storage bin located along the east side of the boiler house. This green coal bunker is provided with a sloping bottom which discharges coal by gravity to spouts leading to 12 Raymond pulverizers located directly beneath. There are no driers installed at present, although the plant is so designed that driers may be installed at any time, if desired.

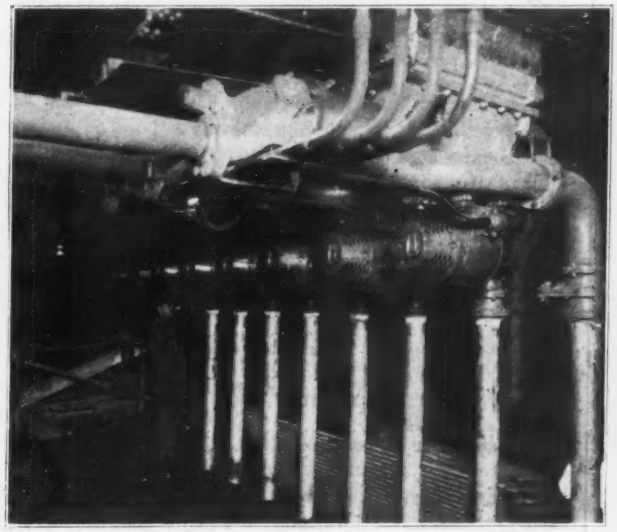


FIG. 5. BATTERY OF EIGHT FEEDERS SERVES THE BURNERS FOR ONE SIDE OF THE BOILER

Summary of Mechanical Equipment in Cleveland Electric Illuminating Co. Plant

Boilers

Manufacturer.....Babcock & Wilcox Co.
Number 4
Type.....Class 13 Twin Set Stirling
Steam pressure 275
Rating .....3060 hp.
Heating surface, sq. ft.....30,592
Furnace volume, cu. ft.....29,150
Ratio furnace volume to water heating surface.....0.95
Heating surface per kilowatt installed.....1.44
Superheaters.....Babcock & Wilcox Co.
Type.....Convection, two for each unit
Superheating surface, sq. ft. each.....6822
Ratio total superheating surface to boiler heating surface 0.446
Economizers.....Power Specialty Co.
Number.....2 per unit Type.....Foster
Heating surface, sq. ft.....22,464
Ratio economizer surface to boiler heating.....0.73
Heating surface per rated b.hp. in sq. ft..... 7.3
Soot blowers.....Vulcan Soot Cleaner Co.
Type—Ratchet head.....28 units per boiler
Arches.....Detrich Arch Co.
Ash gates, pneumatic type.....Baker-Dunbar Co.

Pulverized Coal Equipment

Lopulco system.....Combustion Engineering Corp.
Number of mills.....12 Capacity each, tons per hr...6
Number of burners per boiler.....16
Proximate analysis of coal used—
Moisture.....4 to 5 Fixed carbon.....33.0
Volatile matter .....53.0 Ash 14.0
Heat value, B.t.u.....12,500 dry basis

Induced Draft Fans

Manufacturer.....B. F. Sturtevant Co.
Number per unit.....2
Type—10 ft.....Cindervane
Capacity, cu. ft. min.....95,000
Ash elimination guarantee, minimum.....50 per cent
Drive, 150 hp. A.C. brush shifting motors.General Electric Co.

Stacks

Builder.....Rust Engineering Co.
Number (one for each boiler).....4
Material.....Radial Brick
Height above burners, ft.....238
Diameter at breeching.....14 ft. 2 in.
Diameter at top.....12 ft.
Stack area per 1000 sq. ft. of boiler heating surface, sq. ft. 3.70

Turbo Generators

Manufacturer.....General Electric Co.
Number of units.....1
Rating .....30,000 kw.
Type.....17-stage, single-cylinder
Steam at throttle.....250 lb. Temperature..685 deg. F.
Generator.....11,430 v., 60 cyc., 3 phase, 1800 r.p.m.
Water rate guarantee at rating at 1 in. back pressure, lb. 10.25
Rated at 85 per cent P. F. Eff.....96.5 per cent
Exciters, direct connected.....General Electric Co.
Ratio exciter capacity to generator capacity.....0.007

Generator Cooling

Closed system.....80,000 cu. ft. min.
Air conditioning system.....Carrier Engineering Co.

Condensers

Manufacturer.....Worthington Pump & Machinery Corp.
Number of tubes, 1 in. diameter.....10,130
Material of tubes.....brass
Total tube surface, sq. ft.....53,000
Sq. ft. tube surface per kw. of turbine.....1.77
Cooling water per lb. of steam, lb.....8.34
Steam condensed per hour per sq. ft. tube surface, lb.....6.2
Capacity, guarantee, lb. steam per hr. at 1.0 in. back pressure, 50 deg. F. cooling water.....330,000
Packing, metallic.....John Crane Co.
Air removal.....Worthington steam jet
Circulating pumps.....2 for each unit
Worthington volute pumps driven by General Electric Co. turbines through 3560/388 reduction gear and one driven by G. E.....200-hp. motor
Capacity, g.p.m. each.....35,000
External head.....20 ft. Suction lift.....7 ft.
Circulating pump capacity, g.p.m. per kw.....1.82
Intake cross section in sq. ft. per 1000 g.p.m.....0.58
Condensate pumps .....Worthington
1—780 g.p.m., driven by 60-hp. 1200-r.p.m., a.c. motor.
1—780 g.p.m., driven by 55-hp., G. E. turbine.
Discharge head.....110 ft.

Feed Water Heaters

Manufacturer.....Worthington Pump & Machinery Corp.
Open type, one for each boiler, lb. per hr.....400,000

Boiler Feed Pumps

Manufacturer.....Lea-Courtenay Co.
Type, 4-stage centrifugal, number installed.....4
Capacity, 1200 g.p.m.....2400 r.p.m.
Drive, 390-hp. turbines.....Terry Steam Turbine Co.

Service Pump

1—1000 g.p.m.....Lea-Courtenay Co.
Also an interconnection with old part of plant.

Piping and Accessories

Piping contractor.....Pittsburgh Pipe & Equipment Co.
High pressure steam valves.....Chapman Valve Mfg. Co.
Safety valves per boiler, 10—4½ in. on steam drums, 4-3—in. on superheater outlets—Form A Consolidated.
Non-return valves on steam lines.....Foster Engineering Co.
Check valves on feed lines, 4 in.....Edward Valve & Mfg. Co.
Blow-off valves, 6 per boiler.....Yarnall-Waring Co.
High pressure globe and angle valves.....
.....Crosby Steam Gage & Valve Co.
Atmospheric relief valves, multi-port.....
.....H. S. B. W.-Cochrane Corp.
High pressure steam joints.....Van Stone

Instruments

Draft gages, one 6 scale multi-pointer per unit Bailey Meter Co.
CO_2 meter.....Bailey boiler meter
Steam flow meters, 2 per unit.....Bailey
Recording thermometers .....Bailey
Steam gage, 4 on rear drum.....Babcock & Wilcox
Vacuum recorder.....Uehling Instrument Co.
Temperature indicator generator windings.General Electric Co.

Miscellaneous Equipment

Belt conveyors.....Robins Conveying Belt Co.
Gantry crane, capacity 120 T. per hr.....Brown Hoist Co.
Locomotive cranes (3), capacity 50 T. per hr.....
.....Browning Engineering Co.
Coal crusher, capacity 75 T. per hr..Robins Conveying Belt Co.
Track scale.....Standard Scale & Supply Co.
Water screens, Rex traveling type.....Chain Belt Co.
Turbine room crane, 100 T.....Cleveland Crane Co.
Ash disposal, steam jet type.....Conveyors Corp. of America
Oil filtration, Richardson Phenix.....S. F. Bowser & Co.
Furnace contractor.....Geo. Allen & Son

Coal is pulverized in 12 Raymond impact pulverizers, each having a rated capacity of 6 T. per hr., grinding to a fineness of 65 per cent through a 200 mesh, 85 per cent through 100-mesh and 98 per cent through 50-mesh. Operation at an average rating of 225 per cent for 24 hr. would require 1000 T., which could be handled by 10 mills operating 16 hr., leaving two mills as spare units.

As the coal is ground to the proper degree of fineness, it is lifted by means of air suction through a pipe leading to an exhauster above each mill and is blown to a cyclone separator, located above the pulverized fuel bin. At this point the pulverized fuel is separated from the air which returns to the mill, air circulation being entirely enclosed and dust tight. At this installation the pulverized fuel is elevated a distance of 110 ft. solely by means of the mill exhauster.

These 12 collectors discharge one-half of the prepared coal directly to the pulverized fuel bins which serve one side of the four boilers, and discharge the other half to a screw conveyor arranged to feed the coal to downspouts and thence to a pair of cross conveyors at a lower level. These conveyors in turn discharge to two distributing conveyors above the pulverized fuel bins which are located on the west side of the house and which serve the opposite side of the four double-end boilers.

Present operating records show that the energy consumption per ton for the pulverizing and handling amounts to about 14.5 kw.-hr. for pulverizing, 1 kw.-hr. for operating screw conveyors, and 4 kw.-hr. for operating feeders and blowers.

As has previously been indicated, an automatic scheme has been worked out for controlling the various factors which influence combustion. This system has been developed by the Bailey Meter Co. with the steam pressure and the steam flow, air flow as the basis of control.

In controlling the air to the furnace the required variation is taken care of by changing the amount drawn through the horizontal air ducts shown in Fig. 1. The primary air, or that entering the furnace through the burners with the powdered fuel is a fixed percentage of the air requirements, or about 20 per cent of the total.

Special Dampers Used For Controlling Air

Due to the great height of the furnace, it is obvious that when admitting air to the hollow wall ducts the tendency would be for more of it to come in at the bottom than at the upper opening, due to the chimney action within the furnace creating a stronger draft at the lower level. In order to maintain a substantially equal distribution of air to the different ducts and to maintain this substantially equal at different ratings, it was necessary to design a register which would change its openings according to the furnace draft, but with the amount of opening at each level governed according to the elevation below the top of the furnace. This has been done by using a spring damper which opens wider as the draft increases and closes as the draft decreases. These dampers are placed at the entrance of the air ducts and are hinged about a vertical axis at one side, so that the air forces the damper open against the pressure of the spring—the damper being curved so as to minimize the resistance to flow.

The springs are so adjusted that the dampers on the lower levels are not opened so much for the same changes in furnace draft as on the upper levels, thereby accomplishing the desired distribution of air to the various ducts at different boiler ratings.

Primarily the control system is operated by steam pressure as an indication of need for more fuel and air to be supplied to each of the furnaces, and the air is continuously readjusted by the steam flow—air flow in order to maintain the desired percentage of excess air for best combustion efficiency at all times. In order to maintain a substantially constant furnace temperature, the percentage of excess air is somewhat higher at high ratings but after this relationship is once established the control system will maintain the proper relationship between fuel and air supplied to each boiler.

Draft in the furnace is maintained in accordance with the load on the boiler by means of the stack damper and induced draft fans. For example, starting from no load the stack dampers open gradually to full opening as the load comes on. When the load demands become greater than can be handled by stack draft alone the induced draft fans are started up. At lower speeds the fans work in conjunction with the dampers but as the load goes up the dampers stand wide open and the swing of the load is cared for entirely by the variation in the speed of the induced draft fans.

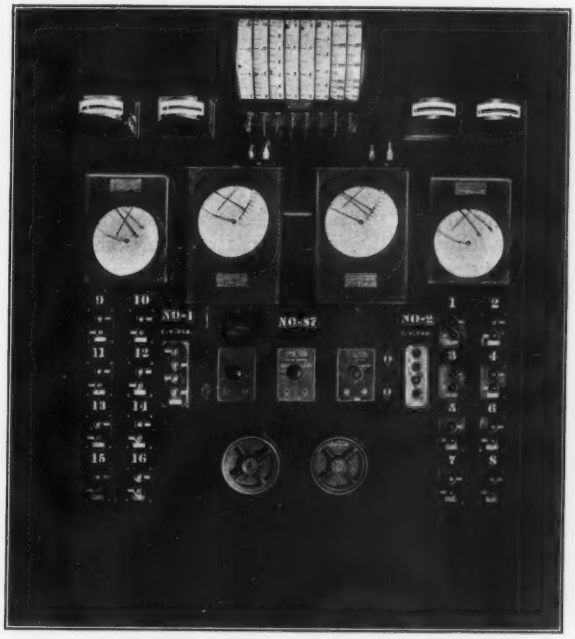


FIG. 6. COMBUSTION CONTROL PANEL FOR EACH BOILER

In this scheme of control the brains of the system is in a special Bailey boiler meter which shows the total steam flow and the air flow through each side of the boiler. As the steam flow increases, an electrical contact arrangement speeds up the feeder motors, and the air supply is increased by increasing the flue damper opening or the speed of the induced draft fan as previously explained.

On the control board, the instruments provided are: one temperature recorder with four pens, reading the temperature of the flue gases on each side of each of the two economizers; one recorder showing the total steam flow from the boiler and the air flow through each side of the boiler; one recorder showing the steam flow from one side

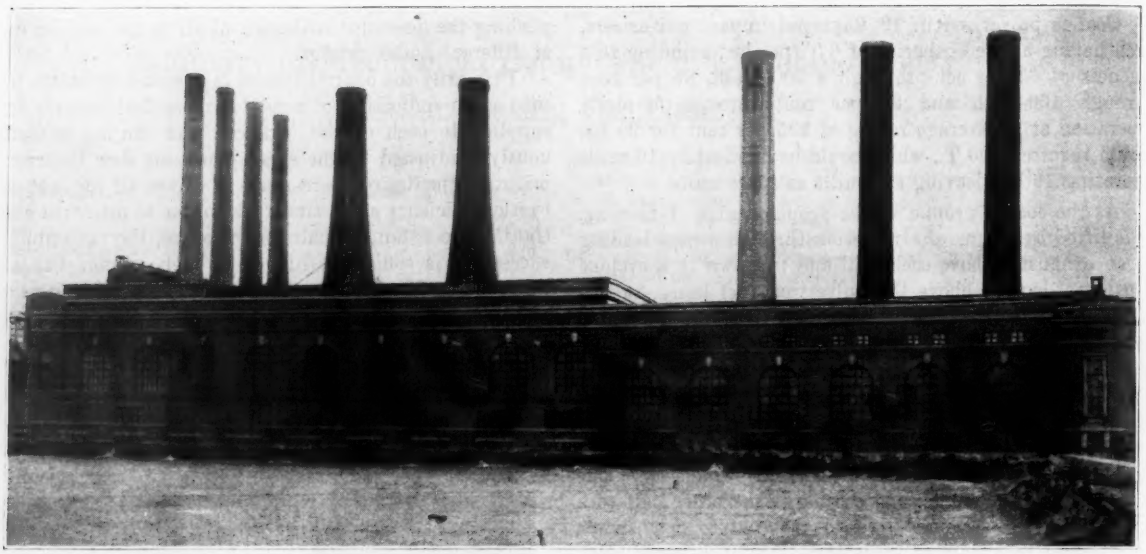


FIG. 7. EACH OF THE NEW BOILERS HAS ITS OWN STACK AS SHOWN BY THE FOUR STACKS AT THE LEFT

of the boiler and the draft in the furnace; one recorder giving the temperature of the steam leaving each side of the boiler and the temperature of the feed water leaving each economizer; indicating draft gages showing draft at various points in the setting; and ammeters showing current for driving the fans and feeders.

Although at the present time only one new 30,000-kw. turbo-generator unit has been added to the Lake Shore station it is expected that one more such unit will be added shortly. A view of the latest unit is shown in the foreground of Fig. 8. The two units at the rear of this unit comprise the installation for the original No. 2 section of the plant. In the far background, the old part of the station with its vertical turbines may be seen.

There are four of these vertical units rated at 15,000 kw. each. These are General Electric Co. units and have been in operation since 1912.

As it is possible to start these vertical units quickly and to get them in on the load in a shorter time than the horizontal type, it is expected that these units will be used mainly for peak load demands. It is interesting to note that the record time for starting up one of these units and getting it on the line is about 6 min., while the best record with the horizontal units is about 30 min.

At the present time the rated capacity of the Lake Shore station is 228,000 kw. and with the two units which are soon to be added this will be brought up to 288,000 kw.

Details of equipment for the new section are given in the accompanying tabulation and some of the design ratios which have been used are also shown.

In the preparation of this article, we are indebted to John Wolff, mechanical engineer, and C. D. Zimmerman, efficiency engineer of the Cleveland Electric Illuminating Co. for data furnished. McClellan & Junkersfeld acted as consulting engineers in connection with the preliminary design of the extension.

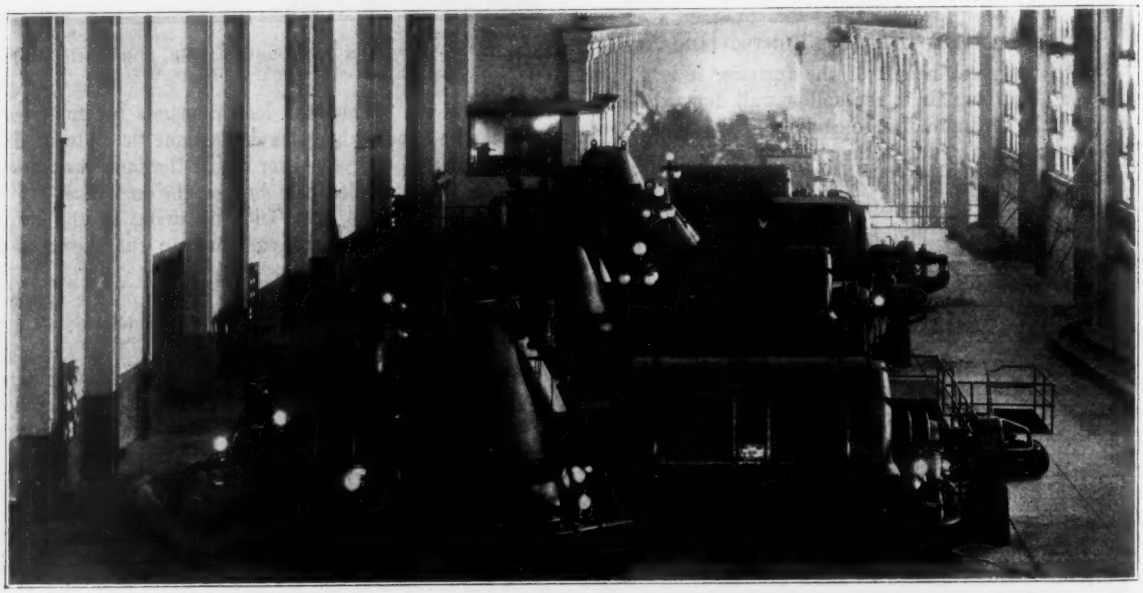


FIG. 8. UNIT IN THE FOREGROUND IS THE 30,000-KW. MACHINE

Requirements for Burning Pulverized Coal

DRYNESS, FINENESS, GOOD AIR MIXTURE, HIGH TEMPERATURE NEEDED. BY S. C. MARTIN

IN BURNING coal, the elements in the fuel must be separated by heat and raised to ignition temperature before they can combine with the oxygen in the air in the process known as combustion. When at this temperature, a sufficient quantity of pure air must be present and in intimate contact with the fuel in order to supply immediately the requisite amount of air to combine with these elements if rapid and complete combustion is to be obtained; for, if sufficient air is not available, or its contact with the fuel is not complete, the speed of combustion is retarded and carbon monoxide (CO) may be formed; or, if the fuel is unable to come in contact with air before its temperature has fallen below the ignition point, it will pass off as smoke.

Advantage gained by pulverizing the fuel is due to the enormous extent of surface afforded by the finely divided material for contact with the air and to the rapidity with which these fine particles can be raised to ignition temperature; but, in order to obtain the full benefit of pulverization, the fuel must be introduced into the furnace and burned under proper conditions.

General requirements for burning pulverized coal with maximum efficiency in the boiler furnace may be outlined as follows:

1st. The moisture in the fuel must be eliminated as far as possible.

2nd. The pulverization must be thorough.

3rd. When pulverized and introduced into the furnace, the fuel must be brought into contact with the requisite amount of air for its complete combustion and the relative proportions of fuel and air closely regulated.

4th. The mixture should be burned in the presence of a refractory which radiates heat to assist in maintaining combustion.

5th. The supply of air as it comes in contact with the burning fuel should be kept as free as possible from contamination with the inert furnace gases.

6th. There must be no localization of the heat on certain portions of the furnace walls or heating surface.

7th. The ash resulting from combustion must not be allowed, when at a high temperature, to come in contact with unburned fuel, otherwise slag may be formed.

In regard to pulverization, it may be stated that coarsely pulverized fuel and even relatively large pieces will burn in a high temperature furnace but a greater length of time, consequently a longer flame travel, is required to complete the combustion than would be the case if the particles were smaller. The pulverization therefore should be as fine and as uniform as possible for, the finer the particles, the more rapid and more perfect the combustion, the shorter and hotter the flame, and the smaller the furnace volume for a given rating.

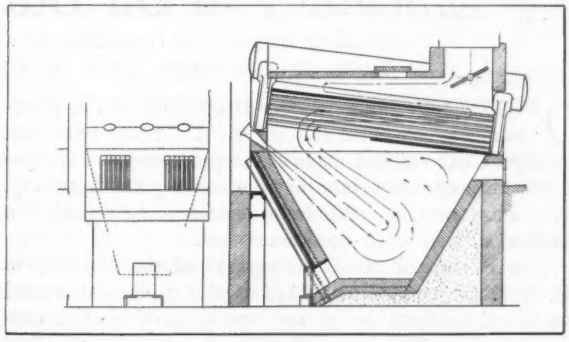
Surface moisture influences, directly, the rate of combustion, the moisture forming envelopes around the particles of fuel which protect them from the action of the heat; also heat is lost in converting this moisture into superheated steam and passing it up the stack. Moist and even wet coal may be pulverized and burned but not with the highest efficiency, and, if there is any considerable amount of moisture present, less heat will be wasted by evaporating it at 212 deg. outside the furnace than by superheating from 400 to 500 deg. within it.

The total amount of air necessary for combustion should be mixed with the fuel as it enters the furnace and the velocity of the mixture, as it issues from the burner, should be as low as possible, so that the burning particles are not projected ahead into the zone of inert furnace gases.

It is of advantage to use preheated air for mixing with the fuel and this may be supplied by an air preheater.

In order that the effective furnace volume may approach as closely as possible the actual volume, the furnace should be properly dimensioned and dead space avoided.

Hard, glassy slag in the pulverized coal furnace can be formed by the action of carbon on the ash when the latter is at a high temperature and any condition in the furnace



AN EFFICIENT POWDERED COAL FURNACE

which will allow carbon to come in contact with ash is liable to cause the formation of this slag. Such a condition may be caused by admitting to the furnace too much fuel in proportion to the air, or by a sudden lowering of the flame temperature, such as might occur in a heating furnace by the introduction of cold material and which would result in some of the carbon in the fuel not reaching ignition temperature. Slag should not be confused with ash which has become melted and cooled into a solid mass and which is friable and easily removed.

In the illustration is shown a front elevation and longitudinal section of a pulverized-coal-fired furnace in which excellent combustion efficiency was obtained.

This installation was made in 1914 by a large manufacturing firm for the purpose of determining the advisability of substituting pulverized fuel for stokers that were then in use in the plant. The furnace was built under a Heine water-tube boiler rated at 272 hp. and was hopper shaped so that the effective volume was increased, the lining being ordinary fire brick. Three burners were placed in the front wall of the furnace but only two of these were in use at any one time, the third being a reserve in case either of the other two became, for any reason, inoperative.

Air for mixing with the fuel entered the burner at a low pressure (about 0.3 in.) and the fuel was pulverized

to such fineness that 80 per cent would pass 200 mesh and 90 per cent would pass 100 mesh, the moisture having been eliminated down to 1 per cent.

Flame extended downward at an angle, for a distance of from 4 to 5 ft. from the burner and then curved upward and backward before striking the brickwork. No air was admitted to the furnace except that which was mixed with the fuel and which entered through the burner; this air was not preheated.

Coal that was burned in this furnace was bituminous slack containing about 13,800 B.t.u. and analyzing 28 to 32 volatile and 59 to 61 fixed carbon. The temperature in the furnace ranged from 2400 to 2700 deg. F. and at no time was slag formed within this temperature range except when ash at a high temperature came in contact with unburned fuel. This could and did occur at times when the regulation was poor and too much coal in proportion to the air was admitted to the furnace; but, as soon as regulation was again effected, the formation of slag ceased. Ash in the form of powder accumulated at the bottom of the furnace and was easily removed.

The furnace was in continual daily service for over 2 yr. without having been changed or repaired and during this time the CO_2 was maintained between 15 per cent and 18.4 per cent. Numerous charts taken from the CO_2 recorder showed practically straight lines for continuous runs of 24 hr.

Four tests were run on this installation, varying in length from 8 to 22 hr. and the furnace temperature as measured with a radiant pyrometer did not at any time during these tests exceed 2400 deg. F., the average CO_2 maintained being 17.8 per cent. There was no CO.

No special training was necessary for the operator in order to enable him to maintain a constant high percentage of CO_2 with varying demands on the boiler, the fuel and air mixture being easily controlled.

Results obtained with pulverized coal in this furnace would indicate that high CO_2 may be maintained with this type of fuel without danger to the brickwork from excessively high temperatures and without the formation of slag, provided the furnace can be properly designed and the requirements for maximum efficiency adhered to.

Efficiency in Oil Burning Installations---I

Correct Design and Operation of an Oil Burning Furnace Can Reclaim Much of the Waste That Is Now Going Out. By F. A. Rothwell

DURING 1921 approximately 315,000,000 bbl. of petroleum was consumed as fuel. No doubt that since then this figure has reached magnificent proportions. Apropos of this we may safely state that the power plant fraternity, the country over, has definitely decided that fuel oil is a practical as well as an economical fuel.

The Bureau of Mines states that of the 315,000,000 bbl. of fuel consumed in 1921, 78,750,000 bbl. was wasted due to unintelligent design and operation of the fuel consuming units. This means that 25 per cent of all the fuel oil used was useless waste and could have been prevented by proper application of the basic principles for the promotion of efficient combustion.

Fuel oil is, primarily, a product of petroleum. It may be straight petroleum, such as Mexican crude, or a byproduct of petroleum. A byproduct of petroleum is the residue of the still after the lighter fractions have been distilled off. Fuel oils will range between 18,000 and 19,000 B.t.u. per lb. and the viscosity will vary with the depth of the "cut" made by the lighter fractions. The value of the lighter stocks in the crude makes it prohibitive to use the straight crude for fuel and the reduced petroleum is much more safely handled due to the fact that the lighter fractions are removed, thereby eliminating the danger of forming gas which may become ignited.

Fuel oil is purchased on a volume basis, a barrel (42 gal.) being the standard unit. In purchasing fuel oil we sometimes come upon some interesting facts. One of the most interesting came to my notice sometime ago concerning the purchase of fuel oil on a B.t.u. per pound basis. The purchaser complained that the fuel having the most B.t.u. per pound evaporated the least water per quantity of fuel consumed. The matter seemed complicated until explained in the following manner. As the weight of the fuel increases, per barrel, the B.t.u. per barrel increases but as the B.t.u. per pound increases, the B.t.u. per barrel decreases. This is due to the fact that a barrel of fuel of 17 deg. Bé. weighs about 330 lb. per bbl. and contains approximately 18,800 B.t.u. per lb. or 6,204,000 B.t.u. per bbl., while a fuel of 27 deg. Bé. weighs about 312 lb. per bbl. and contains approximately 19,400 B.t.u. per lb. or 6,052,800 B.t.u. per bbl. It is evident, therefore, that it is quite in line to purchase the fuel of the least heating value per pound which contains more heat units per unit volume, the basis on which the fuel is bought. If, however, we were purchasing the fuel on a weight basis, it would be more economical to select the fuel of the lighter gravity and more heat units per unit weight.

Furnace Design

Ordinarily the design and operation of an oil burning system is not as complicated as some would have us think. One type of furnace, properly designed, is quite easily adapted for all natures of petroleum fuel. The fundamental idea of any furnace is to oxidize completely the combustible components of the fuel in order that the greatest amount of heat may be utilized in useful work. It is not the furnace, of course, that does the oxidizing but it is admitted that without the proper arrangement of the furnace the process is greatly impaired.

There are two main factors entering into the design of an oil burning system; furnace arrangement and selection of burners. Other important items are storage, pumping and ease of operation. In the construction of the furnace it is ever important to convert every available cubic foot of space into combustion space. It is good practice to allow between 2.0 and 2.5 cu. ft. per rated boiler hp. if it is found necessary to raise the setting in order to obtain sufficient space to allow for a desired over rating of the boiler.

Ofttimes the advisability of changing from coal to oil is questioned. There are a score or more of subjects that come in for serious consideration that can only be determined by those directly concerned in the matter. In any event, the change means discarding all equipment pertaining to stokers which in itself represents quite an expendi-

ture of money on which a substantial return through the sale of the discarded equipment is doubtful. In the event it is desired to convert a furnace from coal to fuel oil by the elimination of unnecessary ignition arches, bridge walls and the abandonment of stokers, then, as the steaming capacity of a boiler is limited only by the amount of fuel that can be burned under it, the greatest possible amount of combustion space should be allowed.

Another interesting point in the design of an oil burning furnace is the fact that the best results are obtained from furnaces whose walls are free from projections of any kind. Under no circumstances is it advisable to install splatter walls to facilitate ignition. Usually these splatter walls are placed about 5 or 6 ft. in front of the burner in the path of the flame. This arrangement is supposed to keep the wall incandescent in order to help support combustion. The practice is fundamentally erroneous and is not at all necessary with a properly designed furnace. These walls tend to localize the heat and if the boiler water carries any degree of hardness it will be precipitated much more readily at this point, causing undue bagging and blistering. The temperature of the furnace is always sufficient to support combustion if the introduction of air is handled in the right manner. All that is necessary or desirable in the furnace is four walls that rise straight from the floor to the tubes. This gives us a box-like affair with the lower row of boiler tubes forming a "roof."

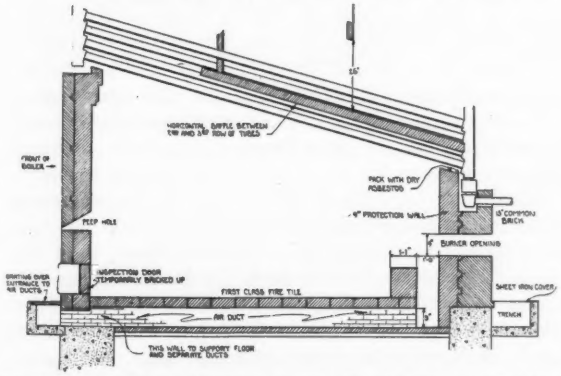


FIG. 1. MAXIMUM POSSIBLE FURNACE VOLUME IS OBTAINED WITH REAR SHOT BURNERS

Another important item to keep in mind is to have the distance from the burner tip to the first pass as great as possible. When we convert all of the available space of the boiler for combustion space and the burners are properly located, we have the longest possible distance between these two points. This distance is necessary since we have to be absolutely sure that all of the gases are completely burned before they enter the tube area. If these burning particles should reach the comparatively cool surface of the tubes before they are completely consumed, the ignition would be retarded and incomplete combustion would result. The space, through which the expanding gases flow, should increase in height with the expanding gas. In this manner we eliminate the choking effect and increased velocity that a reverse of this order would cause.

For the efficient utilization of fuel oil the most important consideration lies in the introduction of the air for combustion at the theoretically correct point. This point does not vary and is the same with any oil fired installation. It requires but little work to locate this place once we know where to look. In a properly constructed furnace the temperature carried is such that the atomized fuel ignites from 12 to 15 in. in front of the burner tip. This point, where the temperature of the furnace is sufficient to ignite the atomized fuel, is the theoretically correct place to admit all of the air for combustion. Since the oxidation of the components of fuel oil is practically instantaneous, it is therefore advisable to admit all of the air for combustion at this determined point.

Location of Burners

For every 150 hp. of rated capacity it is good practice to supply one burner. Most steam atomizing burners of

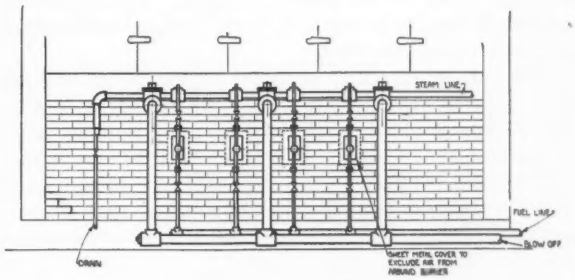


FIG. 2. ARRANGEMENT OF STEAM AND FUEL LINES FOR BURNERS THAT HAS GIVEN SATISFACTORY RESULTS

the No. 2 size are capable of the development of 250 boiler hp. therefore by allowing one burner for every 150 hp. sufficient reserve capacity is at hand to insure adequate capacity for any excessive overloads. A burner functions much more economically at a normal rating of its capacity and as the load increases on the boiler we do not experience an increasing burner loss since we have rated the burners low enough to have them function at their rated capacity with a high overload on the boiler.

Burners should be placed equidistant from sidewall to sidewall and should extend back into the wall through which they should project a distance of 3 to 6 in., depending on the style of burner and shape of the flame. This arrangement necessitates the flaring of the burner opening to accommodate the shape of the flame from the burner. Setting the burners in the wall in this manner utilizes practically all of the furnace for combustion space. The burner should be placed about 27 in. from the furnace floor. This gives a good free passage upwards for the gases and is sufficiently far from the floor to keep the flame from direct impingement, thereby prolonging the life of the floor tile. With this arrangement the gases from the burner ignite almost as soon as they pass the inside edge of the wall and the long mellow flame resulting indicates complete combustion before the gases begin to enter the tube area. Each burner should be supplied with a separate duct for air supply and the air should be brought to the burner in the most practical manner. A false floor seems to be the most advantageous method since it utilizes the incoming air for cooling the floor as well as serving as a preheater for the air. We can see the advantage of this since we help to promote combustion considerably by bringing the temperature of the air for combustion close to the fire point of the fuel oil. These ducts extend the entire length of the furnace floor from the front to the rear of the boiler. A small wall should be erected to deflect

the air for combustion directly into the path of the gases emitted from the burner. The more thorough the introduction of the air into these gases the more complete will the combustion be.

In all cases it is important to enter the air for combustion under the path of the gases; never to the side or above. Heated air has a natural tendency to rise and when admitted under the atomized gases it naturally filters through of its own accord and is augmented considerably by the blast effect of the oil and steam vapors. On the other hand, if the air is admitted above or to the side it does not have the opportunity to mix thoroughly with the atomized gases, as it rises to the line of the tubes and flows toward the first pass all the mixing must be done by the scrubbing effect of the gases in motion. This erroneous application results in low CO_2, lower furnace temperature and considerable excess air.

Combustion should be complete before the gases enter the tube area and there should be no reduction in CO_2 from this point to the point where the gases leave the heating surface of the boiler. With fuel oil it is always possible to have the furnace full of completely burned gases and in order that these gases enter the first pass at their maximum CO_2 content it is essential that all unnecessary passages for air be closed.

Figure 1 shows the general arrangement of all the features as outlined. It will be noted that the unit is fired from the rear instead of the conventional front, a most erratic change from the original setting. It will be seen also that considerable additional combustion space was realized by the utilization of the bottom of the third pass. The air duct is sufficiently large to supply air for combustion for more than 200 per cent rating of a 600-hp. boiler. The horizontal baffle is made of the regular baffle tile used in the B. & W. method of placing which exposes two rows of tubes to the direct heat of the furnace, instead of one as before. By this arrangement we practically double the absorption of radiant heat from the furnace, decrease the work to be done in the comparatively cooler area of the second and third passes and accelerate the circulation in the boiler to a great extent.

Figure 2 shows the general arrangement of the steam and fuel piping for the burners at the rear of the boiler. It is of interest to note that the blowoff equipment does not interfere in any way with this method of applying the burners.

The second and last part of this article will consider the selection of burners, the method of supplying fuel to the burners the necessary auxiliary equipment and the operation of the fuel oil burning furnace.

Operation of Radiant Heat Superheaters

STEAM TEMPERATURE VARIES SLIGHTLY WITH PERCENTAGE OF CO_2; TWO STAGE SUPERHEATING HAS ADVANTAGES

TO MEET the demand of central station power plants for steam temperatures as high as 750 deg. special superheater construction has been made necessary. Convection type superheaters can be built to furnish steam at a temperature of 700 deg. or more but to do so require the use of a large amount of heating surface. To provide space for this surface, the arrangement and baffling of the boiler heating surface must be changed, sometimes to the disadvantage of the boiler proper.

This has resulted in the development of the radiant heat superheater, which is placed in one or more of the furnace walls and is composed of elements having flat metal faces directly exposed to the radiant heat from the combustion chamber. By arranging the surface in this manner, the heat required for high temperature superheating is not only easily obtained but certain other decided advantages are found which are beneficial to the boiler unit operation and maintenance.

The rate of radiant heat absorption is so great that the total heating surface required is small and readily accommodated in the available wall space of the furnace.

By placing the superheater in this way, the boiler heating surface may be designed in the most efficient manner with any desired form of baffling so as to absorb the heat to its best advantage.

The radiant heat superheater replaces with a permanent construction a considerable portion of the furnace brick work, which in these days of high furnace efficiency and heavy overload operation requires expensive repairs. This reduction in furnace maintenance cost is a real advantage to be credited to the radiant heat superheater.

This type of superheater is in an accessible position for maintenance and cleaning. The headers are placed outside the boiler where all joints are convenient for inspection and repair. As it is out of the gas path through the boiler, it has no effect upon the draft loss through the boiler unit.

Results of tests made show that the superheat obtained from radiant heat type superheaters remains fairly constant over a wide range of boiler load; at very high ratings, however, there is a tendency for the temperature to drop. The convection type superheater has a somewhat different characteristic, as the temperature rises with the load up to ratings of around 250 per cent. On account of these opposing tendencies, it has been found desirable to combine the two types of superheaters in the same boiler setting, thus superheating the steam in two stages and securing a uniform steam temperature throughout a wide range of boiler loads. Here also at extremely high ratings, there would be a tendency for the temperature to drop, as both these types of superheaters have this tendency under these conditions of load.

INCREASING SUPERHEAT IN EXISTING PLANTS

Another field open to the radiant heat superheater is in existing plants where there is a demand for increased temperature. In many existing plants improvement in furnace conditions has reduced the superheat obtained from existing convection type superheaters, while in other stations turbine equipment has been installed where a higher superheat can be used to advantage. In both these cases the addition of a radiant heat type superheater in combination with the existing convection type superheaters will build up the steam temperature and increase the economy of the station.

Radiant heat superheaters are of particular interest in connection with large boiler units, especially where these

units are designed to operate at high rating and where a fairly high steam temperature is desired. They may, of course, be installed in smaller units for lower degrees of superheat but their real field lies in the central station where the large boiler unit is used.

Considerable apprehension has existed among those in charge of boiler plants that the radiant heat superheater would be a source of trouble due to tube failures, leaking joints and clinker accumulations but, during the few years this type of superheater has been in use, the freedom from such difficulties has been noteworthy.

In the Lakeside Station of the Milwaukee Railway and Light Co., an initial installation of a radiant heat superheater was made in the side wall of the powdered fuel furnace serving a 1306-hp. boiler, which was also equipped with a convection type superheater. In this particular case, half the steam passes through the convection superheaters and the other half through the radiant type. That heated by convection averages about 610 deg. total temperature, while the radiant heat gives to the steam a temperature of 640 deg., the boiler pressure being 290 lb. The areas of heating surfaces of the different elements are as follows: Boiler 13,060 sq. ft., convection superheater 4010 and radiant heat superheater 176.

Since the initial installation was put into operation eight 1760-hp. boilers have been erected in an extension to the plant, each of which is provided with a radiant heat superheater in the bridge wall of the furnace. These boilers are operated at 200 per cent of their rating, the pressure carried being 290 lb. and the superheated steam temperature 720 deg. or about 300 deg. of superheat. In these boilers the heating surface is divided as follows: Boiler 17,600 sq. ft., radiant heat superheater 440.

It is, of course, impossible to control the amount of superheat at will during operation but it can be varied an appreciable amount. In these furnaces some ash and slag will adhere to the superheater elements; this lowers the final temperature of the steam but by systematic blowing, the temperature can be kept within suitable working limits. In this installation, the superheaters are provided with six soot blowers which are used three times a day, the result being an increase of 40 to 60 deg. in steam temperature following each operation.

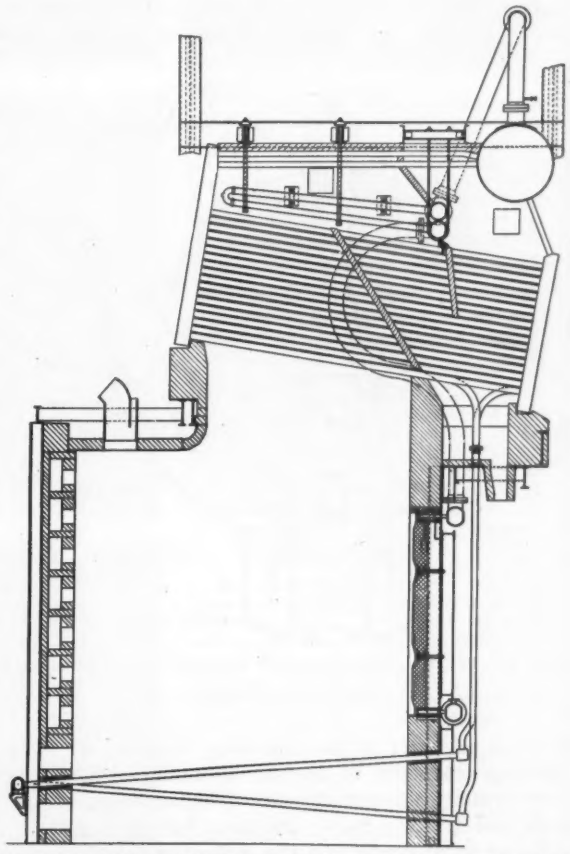
It is noted in operation that variations in the temperature of the steam follow quite closely changes in the percentage of CO_2, which is maintained at about 14 per cent. Recording load and steam temperature charts indicate no appreciable change in superheat with load variation.

At no time has scale been found in the superheaters and the only external cleaning found necessary, aside from dusting with the soot blowers, is the sweeping of the heating surface at times when the boiler is down for inspection or repairs.

In its Westport plant the Consolidated Gas, Electric Light & Power Co. of Baltimore has in service one radiant heat superheater, installed in a 1047-hp. Edge Moor boiler which is 30 tubes wide and 16 tubes high. The superheater is located in the bridgewall and is made up of two passes in series, the individual elements being 5 ft. in length. The boiler is fired by an eleven retort underfeed stoker.

In addition to the radiant heat superheater, the boiler is also fitted with a single loop type convection superheater, located at the top of the first and second passes, which is rated to give 125 deg. superheat. The steam, after passing through the convection superheater, passes through the radiant heat superheater which is designed to add 150 deg., making a total superheat of 275 deg. The boiler normally operates at 200-lb. pressure in the drum.

Such checks as have been made on this installation indicate that there is practically no variation of superheat between 75 and 275 per cent of rating. There has been some tendency for small pieces of slag to collect on the elements which can be blown off by an air lance through the side inspection doors. Apparently such accumulation of slag as has been allowed to collect has had no material effect on the temperature.



RADIANT HEAT SUPERHEATER LOCATED IN THE BRIDGEWALL IN THE LAKESIDE POWER STATION

In the opinion of those in charge of this plant this superheater will materially decrease front wall maintenance, as it apparently lowers the front wall temperature, and will eliminate all bridgewall maintenance.

In operation, when the boiler is first put on the line, before the superheater becomes hot and before the boiler stop valve is opened, it is customary to blow any water that may have collected out of the superheater through a drain in the bottom header. As this superheater was largely experimental it was put through the most severe service that it could possibly be called upon to meet. Under these conditions the temperature of the elements, as measured by thermocouples embedded in the faces, does not exceed 1000 deg. F. From all indications, this temperature has had no bad effect on the material of which the elements are made.

Tendencies in Surface Condenser Practice

Elimination of Dead Tube Space, Multiple Air Suction Openings and Variable Water Supply Are Important Factors in Condenser Design and Application

CERTAIN definite trends in the design and application of surface condensers are shown by a survey of recent installations and by the plans for plants now under construction. In the accompanying tabulation and illustrations the features of some of the representative installations are presented which indicate the tendencies in recent practice. The use of steam lanes in order to reduce the pressure drop through the condenser and to maintain a high hot well temperature; graduated tube spacing; elimination of dead tube space by directing the steam flow through all parts of the condenser; multiple air suction openings; reduction in the ratio of cooling surface to turbine capacity through the use of higher water velocities and heat transfer rates; provision for varying the circulating water supply and the increasing use of steam jet air pumps are a few of the points which are apparent from this study.

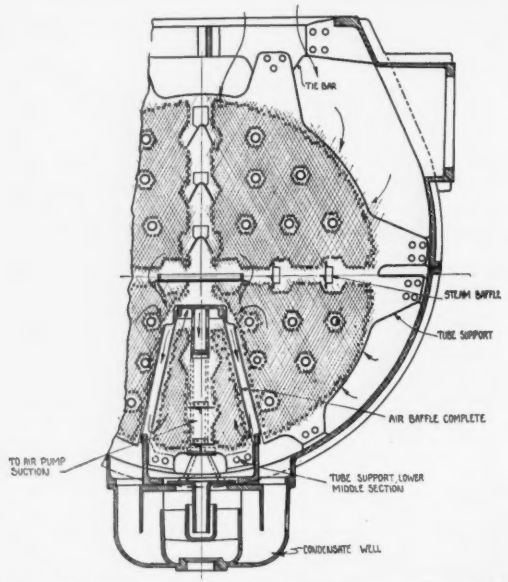


FIG. 1. STEAM FLOWS TOWARD CENTER OF CONDENSER IN THIS ARRANGEMENT

Tube Arrangement Given Much Study

One of the design problems which has been given considerable study by the manufacturers is the effect of tube arrangement on condenser efficiency. At one time it was considered that the more tubes that could be crowded into the condenser shell, the greater would be the vacuum secured. This viewpoint has, however, been changed during the past few years by operating and experimental data which have shown that, by removing a number of the tubes, it was actually possible to increase the vacuum for the same conditions of cooling water and load. The idea has been to provide more definite steam lanes through the condenser and to reduce friction losses.

Figures 1 and 2 show two sectional views of condensers which give an idea how the steam lanes are placed and how the steam flow is directed. In Fig. 1 the exhaust steam enters at the top of the condenser shell and flows around the circumference of the tube bank. The non-condensible gases collect at a point near the center of the tube bank and are then conveyed through a passage to a point near the bottom of the shell. The gases then pass upward through a supplementary bank of cooling tubes and are collected in a cast-iron box extending from end to end of the shell along its center, whence the collected gases are withdrawn through conduits extending out through the bottom of the condenser shell.

With this arrangement of tubes and passages a uniformly convergent passage for the steam is provided and the pass through the tube bank is short, both of which factors are conducive to low pressure drop through the condenser. The condensate, as it enters the hot well, is in direct contact with exhaust steam so that its temperature is raised to near steam temperature. The more condensible gases are given additional cooling before withdrawal from the condenser, thereby permitting more efficient performance by the air removal pump.

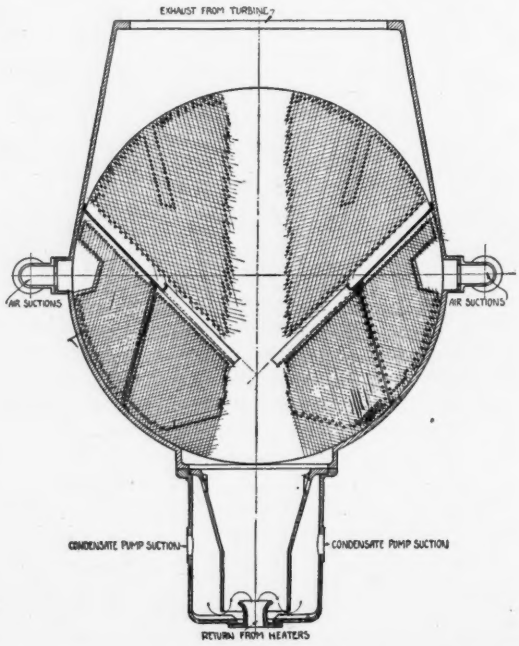
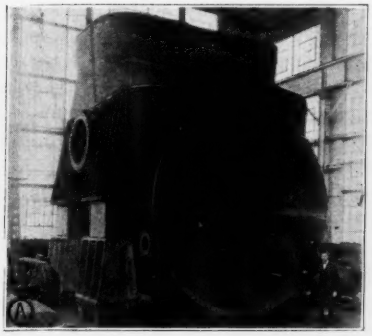


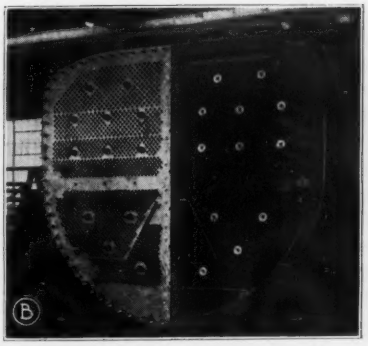
FIG. 2. BAFFLES DRAIN CONDENSATE TO HOT WELL AND PROVIDE PROTECTION FOR MULTIPLE AIR SUCTION OPENINGS

In Fig. 2 the arrangement is somewhat different, although the design secures similar results. This layout is essentially two hemispherical condensers set on edge with a wide steam lane between. Air suction openings extend along each side of the condenser and baffles protect the openings and also drain the condensate into the hot well. One advantage claimed for this arrangement is that an equalized pressure and temperature is obtained at the exhaust opening and at the hot well. Another advantage cited is the reduction in pneumatic resistance between the

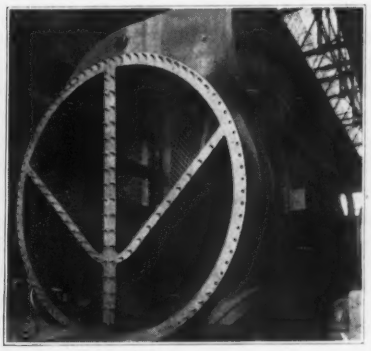
Fig. 3. Some Recent Examples of Condenser Design



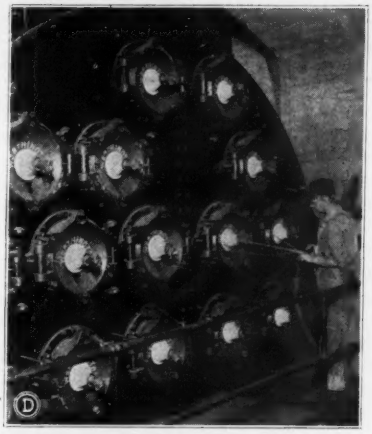
A. 45,000 sq. ft. compartment type condenser built by the Wheeler Condenser & Engineering Co. It will be noted from the tube sheet drilling, that steam lanes are provided, and that the air pump suction is taken from each side of the condenser. Baffles direct the flow of air and non-condensible vapors, the tubes in that part acting as a cooling section.



B. This is a 20,000-sq. ft. condenser built by the Elliott Co. It will be noted that the stay bolts are heavy and that they terminate at the tube sheet, thus keeping the inlet chamber clear. This view also shows the baffling for the air off-take, the divided water box and the baffling and arrangement at the bottom of the condenser shell for obtaining hot condensate. Graduated tube spacing is also used.



E. Condenser under construction in the new Trenton Channel plant of the Detroit Edison Co. This condenser with 52,000 sq. ft. of surface will handle the steam for a 50,000 kw. unit. It is a Worthington single pass unit and circulating water is supplied by two 60,000 g.p.m. pumps driven by 325 hp. 255/175 r.p.m., d.c. motors.



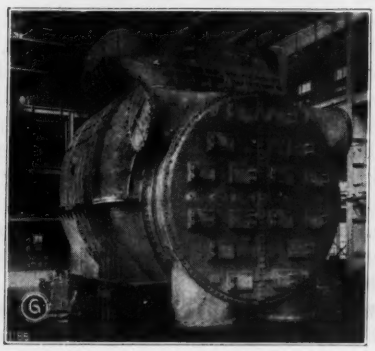
C. 53,000-sq. ft. condenser which is now being installed for unit No. 3 of the Cahokia Station. This condenser is a product of the C. H. Wheeler Mfg. Co. An air box at the center line on each side provides multiple air suction openings. Baffles drain the condensate direct to the hot well and also protect the air suction openings.

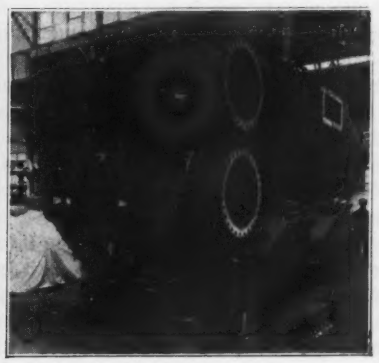
D. Worthington condenser equipped with high pressure nozzles for cleaning. Through the use of a ball and socket joint the operator is enabled to swing the high pressure water jets so that all tubes in that area are cleaned. The frequency of cleaning depends on the kind of circulating water which is used. Where hard scales are likely to form, the intervals between cleaning are decreased.

F. This is the 62,000-sq. ft. Allis-Chalmers condenser which was recently placed in the Calumet Station of the Commonwealth Edison Co. to serve a 30,000 kw. unit. The guaranteed capacity is 400,000 lb. of steam per hr., 28.5-in. vacuum with 70 deg. cooling water. The three other 30,000 kw. units are equipped with Worthington, Westinghouse and Wheeler Condenser & Engineering Co. condensers. Two motor driven circulating pumps are provided for each unit.

G. The new Hudson Ave. station of the Brooklyn Edison Co. has the largest single shell condensers which have been built. This view gives an idea of the size of these 70,000-sq. ft. units which were built by the Westinghouse Electric & Mfg. Co. Two 50,000 g.p.m. motor driven circulating pumps supply the cooling water.

H. One feature of the Ingersoll-Rand condenser is the use of cooler sections which are fastened to exterior of the condenser shell. The illustration shows a condenser with twin coolers. In this condenser the shell is divided horizontally into three sections and the circulating water flows through the top section in a single pass while the flow through the two lower sections is two pass.





exhaust opening and the air pump suction due to the minimum depth of tube resistance.

Since the volume of steam decreases as it flows through the condenser, due to condensation, the use of graduated tube spacing is employed in many designs. This graduated spacing may be obtained by an actual change in center to center dimension in the tube sheet drilling, or for manufacturing reasons, the tube sheet may be drilled uniformly and after the tube layout with graduated spacing has been made, the holes not used are plugged up. For that reason a view of the drilled tube sheet may not indicate the actual arrangement of tubes.

Figure 4 shows a sectional view of a condenser in which graduated spacing is used. This condenser also

rates of heat transfer, smaller tubes are in use, down to as small as ⅝ in.

Although some installations are noted in which a brass composed of 70 per cent copper and 30 per cent zinc is used, the stations depending on fresh water for cooling seem inclined to favor Muntz metal which is 60 per cent copper and 40 per cent zinc. On the coast, where salt water is used for cooling, Admiralty alloy made up of 60 per cent copper, 39 per cent zinc and 1 per cent tin, offers a greater resistance to corrosive action.

Rolling the tubes into one tube sheet which has been standard practice in marine work for a good many years, has gained many advocates in stationary practice. One reason for its adoption in power plant practice is due to

CONDENSER INSTALLATIONS WHICH SHOW THE TREND OF PRACTICE

Plant	Size Turbine K.W.	Tube Surface sq.ft.	Tube Surface per KW. Sq.ft.	No.of Passes Condenser	Tube Specifications Number	Diam. (In.)	Length (Ft.)	Material	Guaranteed Capacity Vac.or Back Press.	Temp. Water F.	Capacity lb.Steam per hr.	Steam condensed per hr.per sq.ft.of tube surface	Make of Condenser	Circulating Pumps No.	Capacity each G.P.M.	Drive	Type of Air Pump
Hudson Avenue Brooklyn Edison Co.	50,000	70,000	1.40	2	13,368	1	20	Admir.	28.68 28.89	60	625,000 600,000	8.94 7.16	Westinghouse	2	50,000	Motor	Steam Jet & Le Blanc
Crawford Ave.,Chicago Commonwealth Edison Co.	50,000	(1) 65,000	1.30	2	13,100	1	19	Admir.	28.5	70	374,000	5.76	Westinghouse	2	35,000	Motor	Steam Jet & Le Blanc
New York United Elec.Lt.& Pr.Co.	50,000	63,000	1.26	2	12,688	1	19	Admir.	28.89	60	630,000	8.42	Westinghouse	2	45,000	Motor	Steam Jet
Cahokia No.4,St.Louis Union Elec.Lt.& Pr.Co.	35,000	55,000	1.57	2	11,080	1	20	Munts	1.42	70	350,000	6.37	C. H. Wheeler	2	30,500	Motor	R.D.V.
Waterside New York Edison Co.	35,000	50,000	1.43	2	10,022	1	19		28.5	65	400,000	8.0	Wheeler C & E	1	70,000	Turb.	Hydraulic & Steam Jet
Kearney, N. J. Public Service Elec.Co.	35,000	60,000	1.67	2	10,074	1	19	Admir.	28.98	60	300,000	6.0	Westinghouse	2	58,000	Motor	Hydraulic & Steam Jet
Cahokia No. 1 & 2	30,000	58,000	1.77	2	10,100	1							Worthington	2	27,500	(2) Motor	R.D.V.
Cahokia No. 3	30,000	53,000	1.77	2	11,080	1	20	Munts	1.37	70	300,000	5.67	C. H. Wheeler	2	27,000	Motor	R.D.V.
Waukegan, Ill. Pub.Serv.Co.Nor.Ill.	30,000	52,000	1.73	2	9,950	1	20	70-30	1.50	70	330,000	6.34	Allis-Chalmers	1	50,000 33,000	(3) Motor	Steam Jet
Reading, Pa. Metropolitan Edison Co.	30,000	40,000	1.33	2	8,130	1	19	Munts	28.3	70	330,000	8.25	Elliott Co.		45,000	Motor	Steam Jet
Acme Plant Toledo Edison Co.	30,000	45,000	1.50	2	8,185	1	21	Munts	28.5	70	330,000	7.35	Wheeler C & E	1	60,000	Motor or Turb.	Steam Jet
Colfax Station,Pittsburgh Duquesne Light Co.	30,000	55,000	1.83	2	10,800	1	20	Admir.	28.7 28.49	70	285,000 400,000	5.19 7.28	Westinghouse	2	35,000	Motor	Steam Jet
Devon, Conn. Conn.Lt. & Pr. Co.	20,000	40,000	2.0	2	7,640	1	20	Admir.	28.85	60	260,000	6.50	Westinghouse	2	21,500	Motor	Hydraulic
Moline, Ill. Util. Lt.& Pr. Co.	20,000	30,000	1.5	2	5,740	1	20	Munts	2.0	80	195,000	6.50	C. H. Wheeler	2	16,000	Motor	Steam Jet
Fort Worth, Texas Texas Constr. Co.	20,000	40,000	2.0	2	7,275	1	21	Munts	27.5	85	240,000	6.00	Wheeler C & E	1	40,000	Motor	Steam Jet
Venice, Ill. Ill. Pr. & Lt. Co.	20,000	33,000	1.65	2	7,350	1	18		2.0	60			Worthington	(4) 1	20,000	Motor	R.D.V.
El Paso, Texas El Paso El.Ry.Co.	15,000	33,000	2.2	2	7,000	1	18	Munts	1.5	70	204,000	6.18	C. H. Wheeler	2	14,500	Turb.	Steam Jet
Neosho, Kan. Kansas Gas & El.Co.	15,000	27,000	1.80	2	4,902	1	21	Admir.	1.19	69	170,000		Westinghouse	1	26,000	Motor	Steam Jet
Los Angeles, Cal. Los Angeles Gas & El.Co.	10,000	40,000	4.0	5	9,560	1	16	Copper	28.1	80	225,000	5.62	Wheeler C & E	1	40,000	Motor Turb.	Steam Jet
Williamsport, Pa. Lycoming, Pa.	10,000	20,000	2.0	2	4,056	1	19	Munts	28.5	70	140,000	7.0	Elliott Co.	2	24,000	Motor	Steam Jet
Edwardsport, Ind. Util.Pr.& Lt. Co.	10,000	20,000	2.0	2		1	20	70-30	28.5	70	120,500	6.03	Allis-Chalmers	2	12,500	Motor	Steam Jet
Saxton, Pa. Penn Central Pr.&Lt.Co.	10,000	17,500	1.75	2	3,520	1	19	Munts	1.5	70	116,000	6.64	C. H. Wheeler	2	12,000	Motor	Steam Jet
Easton, Pa. Penn Edison Co.	10,000	8,500	.85	1		7/8	20		28.35	70	158,000	18.9	Ingersoll-Rand				
Montville, Conn. Eastern Conn. Pwr.Co.	10,000	17,500	1.75	2	3,516	1	19	Admir.	28.5	70	118,000	6.74	Wheeler C & E	2	10,800	Motor	Steam Jet
Cedar Rapids, Ia. Iowa Py.& Lt. Co.	10,000	18,000	1.80	2	4,500	1	16	Munts	1.0	45	140,000	6.70	Worthington	1	18,000	(5) Motor	R. V. D.
Portland, Ore. Northwestern Elec. Co.	8,000	16,000	1.88	2	2,860	1	20	Munts	28.98	60	117,000		Westinghouse	1	20,000		Steam Jet
Marshfield, Oregon Mountain States Pwr.Co.	5,000	7,500	1.5	2	1,768	1	16	Munts	1.0	80	67,500	9.0	C. H. Wheeler	1	11,000	Motor	Steam Jet
Boone, Iowa Iowa Py.& Lt. Co.	3,000	6,250	2.08	2	2,348	3/4	14	Muntz	2.0	(6) 65	45,000	7.2	Worthington	1	5,000	(7) Motor	R.V.D.

(1) Surface is divided in two shells.
(2) 250 hp.390/800 r.p.m.slip ring motors.
(3) Two speed squirrel cage motor
(4) Other pumps in plant can be cut in.
(5) Variable speed motor.
(6) This is a spray pond installation.
(7) Variable speed.

differs from some designs in that supplemental coolers are placed external to the condenser shell. In this design the water passes through the condenser in a single pass, that is through sections A and B while the water passing through section C first passes through the cooler. In some of the most recent condensers of this type, the water passes through section A single pass and Section B is divided for two pass circulation. In this case the water also circulates through section C and the twin coolers in two passes.

At the present time No. 18 gage 1 in. tubes seem to be about the standard size employed in condenser practice. Reference to the tabulation will show that practically all of the installations listed are equipped with tubes of this size. Where the tube surface is reduced and the capacity is maintained through higher water velocities and higher

the higher water velocities which are being used. When the tubes are rolled into the sheet at the entrance end of the condenser, eddy currents are reduced, due to the absence of ferrules, a smooth entrance passage is provided and the possibility of leakage is reduced. The work of tube replacement is, however, increased and so, where high water velocities are not involved, ferrules are generally used on both ends.

Tube packing has come in for an intensive study during the past few years on account of the desire to reduce the water leakage into the condenser. According to the viewpoints expressed by many engineers, fiber, corset lacing and wicking give the best service for packing. It is stated that, unless metallic packing is very carefully handled when the tubes are packed, leakage will be greater than with the non-metallic types. Several cases have

been cited where all traces of metallic packing had disappeared on a part of the tubes of a condenser. The viewpoint that metallic packing reduces the electrolytic action between the tube and tube sheet has, in the opinion of these same engineers, not been substantiated by definite evidence. Many engineers, on the other hand, believe in the value of metallic packing, claiming that it does reduce electrolytic action and that it will give service equal to non-metallic types when properly handled.

Tube cleaning has settled down to a question of opinions among the advocates of four different methods. High pressure nozzles forming a permanent part of the condenser have gained many adherents and numerous installations have been made during the past year. It is claimed by the opponents of this method that the high pressure water jets will not handle hard scale. The advocates of this scheme admit that hard scale cannot be washed off after it has once formed but point out that since cleaning is easy it is possible to increase the frequency of cleaning and to thus prevent the formation of scale. Rubber plugs and mechanical cleaners continue to be used with success and the caustic soda method has some proponents.

Many Large Condensers Now Being Installed

Condenser sizes have had to keep pace with the increasing size of prime movers so that tube surfaces of 50,000 sq. ft. and above are now quite common. The largest single shell condensers yet built are those for the Hudson Avenue Station of the Brooklyn Edison Co. with 70,000 sq. ft. According to the designers of these condensers it would be entirely feasible to construct a single shell condenser of 100,000 sq. ft., if the necessity should arise. In the new Crawford Avenue Station of the Commonwealth Edison Co. the 50,000 kw. units will be equipped with 65,000 sq. ft. of condenser surface although the surface is split up into two shells.

From the tabulation it will be noted that tube surface per kilowatt of capacity varies from 0.85 to 4.0 sq. ft. In most cases the surface varies within the range of 1.50 to 1.75 sq. ft. per kw., although a few years ago 2.0 sq. ft. and above predominated. In some cases higher heat transmission is secured through higher water velocities and smaller tubes with a result that condensers have been built with surface as low as 0.5 sq. ft. per kw.

Among the claims for reduced tube surface, with higher water velocities, is that the scouring action of the higher water velocities tends to keep the tubes free of slime. There is no question but that these higher rates of heat transmission demand clean surfaces and the opposing view on the subject takes the stand that under laboratory conditions it is possible to show the value of these high water velocities and small tubes, but that under actual operating conditions the efficiences cannot be maintained unless at the cost of eternal vigilance. The next year or two will determine whether this tendency toward reduced surfaces is a step forward, as many claim, or is a step backward as it is thought to be by the opposition.

Practically every recent condenser installation shows that considerable attention has been given to securing some method of varying the supply of circulating water. It is quite obvious that the power cost involved in pumping circulating water is considerable and where a cold supply as available as during the winter months, a considerable saving can be made by reducing the water pumped. This not only reduces the pumping cost but also means that higher condensate temperatures can be maintained. This latter point is important when it is considered that many of the new condensers are designed on a basis of condensate temperatures within 1 to 3 deg. of the steam temperature at the exhaust pressure. Several years ago a temperature difference of 10 deg. was considered good practice. It is obvious that refrigeration of condensate may take place if the circulating water is far below that given in the guarantees, unless the quantity is reduced.

Most of the installations use two circulating pumps so that it is possible to cut out one pump if desired. Since the capacity of one pump will be more than half of the combined capacity of the two pumps when operated together, the supply of water is not cut down as much as might be expected. For instance if the pumps are rated at 20,000 g.p.m. each when operated to supply 40,000 g.p.m., one pump alone would supply 25,000 g.p.m. due to the reduction in friction head.

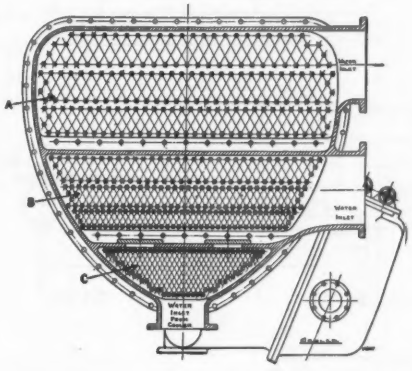


FIG. 4. GRADUATED TUBE SPACING AND SUPPLEMENTAL COOLERS PLACED EXTERNAL TO THE CONDENSERS ARE FEATURES OF THIS DESIGN

As a means of securing still wider variation arrangements are sometimes made to run one of the pumps at constant speed and to vary the other one, either through the use of a turbine drive or through a variable speed motor.

Where one pump is used it is usually driven by a turbine or a variable speed motor. In a few cases a multi-speed squirrel cage motor is used which will give two, three, or four speeds for the pump. One example of this type of drive is the Waukegan Station listed in the tabulation. In this case a 50,000-g.p.m. circulating pump is driven by a two speed squirrel cage motor. The capacity at the lower speed is 33,000 g.p.m.

It will also be noted from the tabulation that while the steam jet type of air pump is used in most installations, the rotative dry vacuum pump is used in a number of important stations. One reason for this is the decrease in the volume of air to be handled due to the effectiveness of the cooler sections in modern condensers. Another reason is the low operating cost of this type vacuum pump. Hydraulic types continue to be used with good results and have many advocates. Because of its low cost and the fact that the heat in steam used is reclaimed, the steam jet type has made rapid progress and at least 75 per cent of present day air pump installations are of this type.

Adapting Evaporators to Heat Balance---I

CALCULATIONS SHOW THAT EVAPORATORS PROPERLY ARRANGED AND CONTROLLED DO NOT INTERFERE WITH HEAT BALANCE. BY ERNEST H. CHAPIN*

IN STEAM power plant practice, the use of distilled water for boiler feed make-up is becoming more and more general. Although the advantages are many, they will not be taken up here; they apply, however, not only to the boiler room operation but extend to the pipe lines and main turbine unit as well.

To produce distilled water, evaporators must be installed. The proper arrangement of the evaporator unit, in correlation with the rest of the station, is of the greatest importance, and the desired heat balance of the station must not be interfered with, if the full station economy of operation is to be maintained.

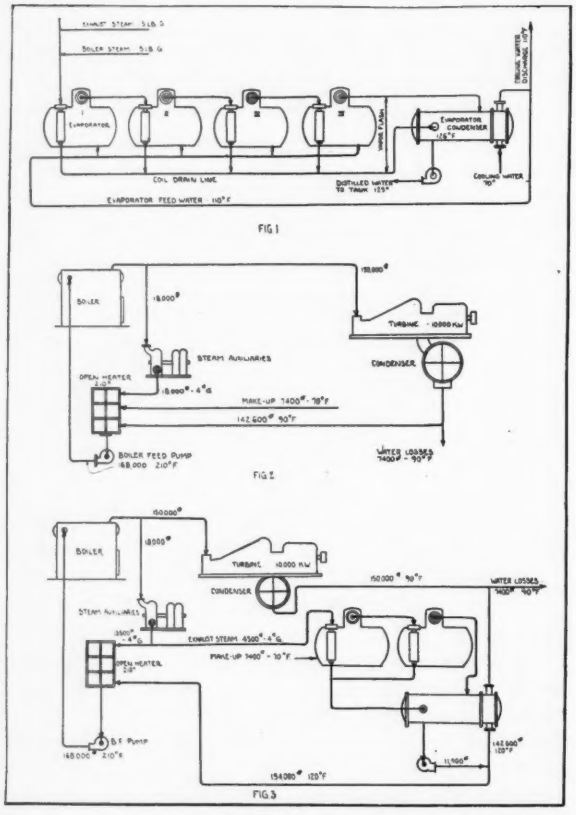


FIG. 1. ARRANGEMENT OF QUADRUPLE EFFECT EVAPORATOR FOR DISTILLING PLANT

FIG. 2. CYCLE A IS FOR A SIMPLE CONDENSING STATION

FIG. 3. CYCLE A-1 PROVIDES FOR A DOUBLE EFFECT EVAPORATOR AND EVAPORATOR CONDENSER

To fit the evaporator unit to the station heat balance, the characteristic features of evaporator operation must be kept in mind. Consider an isolated distilled water plant, such as is used by the U. S. Naval Stations.

Figure 1 indicates the approximate arrangement of the distilling plant now being installed at Guantanamo, Cuba, by the Bureau of Yards and Docks, for Naval use. Steam generated by the boiler passes to the first effect of the quadruple effect evaporator, at 5 lb. gage pressure. Under some conditions exhaust steam is available from a nearby source, but the unit is specifically designed for independent operation. The vapors from the last effect are condensed in a surface condenser at 26 in. vacuum. The water circulating through the tubes of the condenser carries to waste the heat that was supplied the first effect, except for a small amount that is recovered by taking the evaporator feed water from the warm condenser circulating water discharge line. There is no available use for the remainder of the heated water that goes to waste, in such an isolated unit.

Feed water for the evaporator consists of sea water, consequently the residual waste of concentrated sludge is large, being about 35 per cent of the net distilled water obtained. Fresh water evaporation entails much less waste from this source.

The distilled water collected in the condenser, and in the drains from the evaporator effects, is pumped by a hotwell pump to a storage tank.

Thus the operating elements of an isolated plant may be appreciated and used in planning the installation of evaporating equipment in a power station.

Summarized, the vital features of evaporator operation are:

1. Steam supply—at the proper pressure.
2. Proper temperature drop from steam temperature to condenser temperature. This produces the heat head over the evaporator heating surface. Evaporator capacity increases approximately directly in proportion to the increase in temperature head.
3. Raw water supply at proper pressure, and drain of residual sludge, or concentrated blow-down.
4. Adequate supply of condensing water, to carry away the heat in the evaporator vapors condensed.

The operating characteristics of the equipment itself will not be discussed, as only the requirements from the outside standpoint, affect the fitting of the evaporator unit into the station heat balance.

POWER STATION CONDITIONS

In the power station, steam for evaporator operation is available from several points in the cycle. The main condensate, or boiler returns, can be used for condensing water for the evaporator condenser, thus making it possible to recover practically all the heat supplied the evaporator, and making the unit almost 100 per cent efficient, thermally. Such a possibility is usually the case in steam stations using surface condensers, allowing the make-up requirements to be somewhat less than 10 per cent and usually around 6 per cent, maximum. When the make-up increases, the cost of installation of the evaporator goes up if this 100 per cent approximation is to be maintained.

It is on this basis that the application of evaporators to the various types of station cycles will be considered.

One would not be far astray if he stated that there were as many different heat balance schemes as there were power stations. But they can be classified with respect to fundamental types of operation, and also to the character of apparatus installed. On such a basis, the following classification can be made:

*Wheeler Condenser & Engineering Co.

Heat Balance Classification

1. Auxiliary drive—steam or motor drive, or both.
2. Economizers—with or without.
3. Turbine bleeding for stage heating, or simple exhaust steam heating of boiler feed water.
4. Load factor on station, as affecting the heat balance.
5. Number of main units in station.
6. Amount of make-up water required.
7. Other auxiliary equipment installed, as deaerators, air heaters, etc.

These various elements have been applied to practical power station heat cycles and the accompanying diagrams, with the discussion, show the methods of installing evaporator equipment in each of them. All quantities shown are on an hourly basis.

Assumed Conditions

1. Sensible heat of drains or make-up water not taken into consideration.
2. Latent heat of steam at various pressures—1000 B.t.u.
3. Actual operation of the evaporator unit, as residual blowdown, exact heat balance internally, and other conditions pertaining to the evaporator only, are not shown, for simplicity.
4. The turbine output, the kilowatts is not necessarily constant in the various diagrams, but for simplicity, the same amount of steam to the turbine has been assumed constant, namely, 150,000 lb. per hr.

A. Simple Station Cycle

Figure 2 shows Cycle A, a station having no economizers, all steam driven auxiliaries, and no stage heating by bleeding the main turbine. The figures shown are approximate, the whole scheme laid out to appreciate readily the relations of the various parts of the cycle, rather than to depict the exact conditions and quantities of operation, in detail.

A-1. Exhaust Steam Evaporator Unit

Figure 3 shows a double effect evaporator, with its auxiliary surface condenser applied to the station having a cycle shown in Fig. 2. Exhaust steam of 5 lb. gage is bypassed in sufficient quantity to the first effect, and the heat is finally recovered in the evaporator condenser by the main condensate passing through the tubes.

Here the final temperature of the water going to the boilers is obtained in two stages. The first rise is obtained in the evaporator condenser, being 30 deg. F., in the case of the cycle shown. The remainder of the station exhaust steam is absorbed in the station heater, and the heater discharge goes to the boiler at 210 deg. F., exactly the same temperature as was the case when evaporators were not installed. See Fig. 2.

There is no change in the heat balance, although the evaporator in operation decreases the load on the station heater, rather than increasing it. When it is desired to shut down the evaporator, all of the exhaust steam goes to the station heater, the main condensate bypassing the evaporator condenser if desired, and the operation is exactly the same as in Cycle A, Fig. 2.

Figure 4 shows the application of an evaporator unit operating on boiler steam, at boiler pressure, or with a reducing valve in the line. This steam goes to the first effect coils, of the double effect evaporator shown. The boiler feed water, from the boiler feed pump, serves as cooling water for the evaporator condenser, consequently the water enters the boiler at 210 deg. F. + 25 deg. F. or 235 deg. F. An evaporator condenser is provided to withstand the maximum boiler feed pump discharge pressure, and the whole evaporator unit is under rather high pressure.

The drains and distilled water going to the station heater add some heat to the system, usually enough to raise the heater temperature from 4 to 10 deg. F., depending on the quantities. If there is a tendency to have excess exhaust steam from the auxiliaries, there might be a waste of heat from the system, particularly at less than full station loads. A feed pump must be provided to give the water the proper pressure to enter the evaporator bodies,

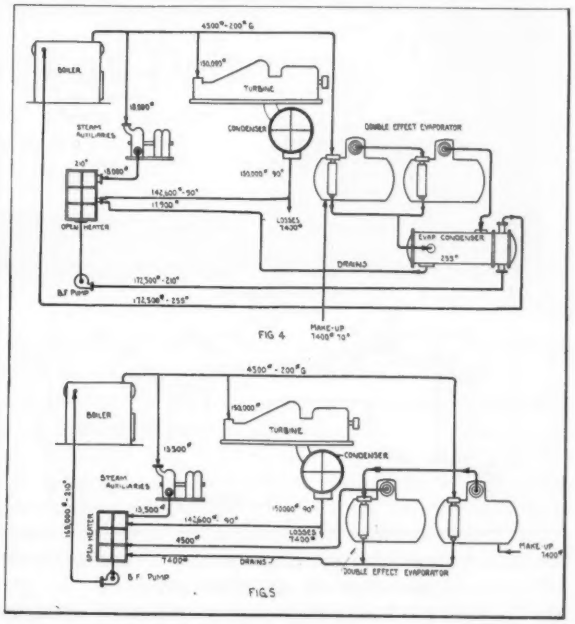


FIG. 4. CYCLE A-2 USES LIVE STEAM FOR EVAPORATING PURPOSES

FIG. 5. CYCLE A-3. THE STATION HEATER SERVES ALSO AS AN EVAPORATOR CONDENSER

and in many cases heaters are installed to preheat the raw water going to the evaporator.

A-3. Live Steam Evaporator Operation Simplifies Arrangement

Figure 5 indicates the station heater being used as the exaporator condenser, thus eliminating the auxiliary as a separate piece of apparatus. Such an arrangement is not particularly practicable for most plants, as it entails the cutting down of the mount of steam to the steam auxiliaries. Assuming a maximum temperature in the station heater of 210 deg. F., the amount of exhaust steam which can be condensed is decreased from 18,000 lb. in A and A-1, to 13,500 lb., shown in A-3. At less than full station load, this would be further decreased, as the requirements on the evaporator do not decrease in proportion to the decrease in station load.

It is therefore not a desirable arrangement, although it simplifies the evaporating equipment. Valuable work is lost by using live steam for heating, where exhaust steam

could be profitably used. It is shown and discussed to bring out the disadvantages more than the advantages of the arrangement.

B. Simple Station Cycle with Economizers

What is designated as Cycle B is the simple station cycle, with economizers added, shown in Fig. 6. The alteration assumed is that a lower feed water temperature is desirable with economizers, and 170 deg. F. has been chosen. This means that approximately only 12,000 lb. of exhaust steam can be condensed in the station heater, consequently there would be, in actual practice, some of the auxiliaries motor driven, or having motor drive as an alternate, for use when operating at less than full load.

It is assumed also, that if deaerating equipment is used

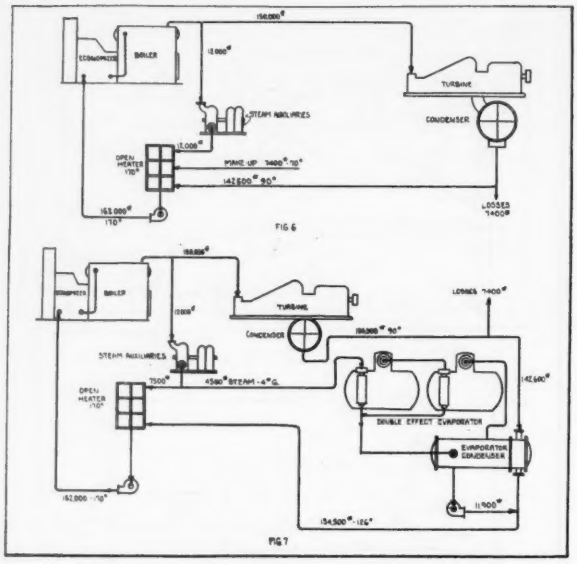


FIG. 6. CYCLE B IS THE SIMPLE STATION CYCLE WITH THE ADDITION OF AN ECONOMIZER

FIG 7. CYCLE B-1 ACCOMPLISHES EVAPORATION OF MAKE-UP WATER WITHOUT CHANGING TEMPERATURE OF FEED TO ECONOMIZER

to protect the economizers from corrosion, they will not affect the cycle, and have therefore been omitted for simplicity.

B-1. Exhaust Steam Evaporator with Economizer

Figure 7 indicates Cycle B-1, installation of a double effect evaporator unit in Cycle B. The critical factor to be considered under such an arrangement is to introduce no element with the evaporator unit, which might tend to decrease the efficiency of the economizers, or limit the flexibility of operation when the station is operating at moderate loads, or changing the load.

With this in mind, it can be observed that the exhaust steam operated evaporator introduces no change in the temperature of the water going to the economizers, as it maintains exactly the same heat cycle as was the case without evaporators, shown in Fig. 6, simply doing the heating of the main condensate and make-up water in two steps, instead of one, and using exactly the same amount of exhaust steam, without introducing steam from any other source. From this standpoint, it is pre-eminently the most satisfactory arrangement from the station cycle standpoint, and incidentally, the low temperatures involved in the evaporation process minimize the possible scale accumulation in the evaporator itself.

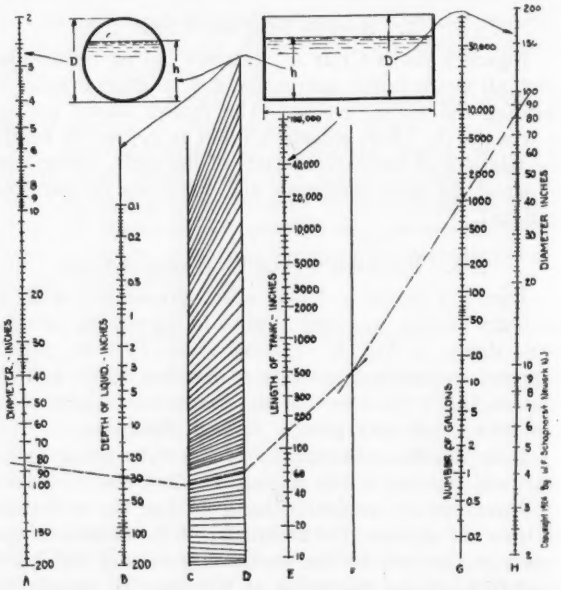
(In the June 1 issue of Power Plant Engineering, Mr. Chapin will discuss the heat balance of cycles in which evaporation is accomplished with steam extracted from the main turbine. Editor.)

Chart Gives Contents of Tank

By W. F. Schaphorst

HERE is a chart that gives the gallons of liquid in any horizontal tank. Start at the left and zigzag a ruler or thread across the chart three times as demonstrated by the dotted line and the number of gallons is immediately found in column G. For example: How many gallons in a tank 84 in. in diameter, the depth of liquid being 30 in. and the length of the tank being 142 in.?

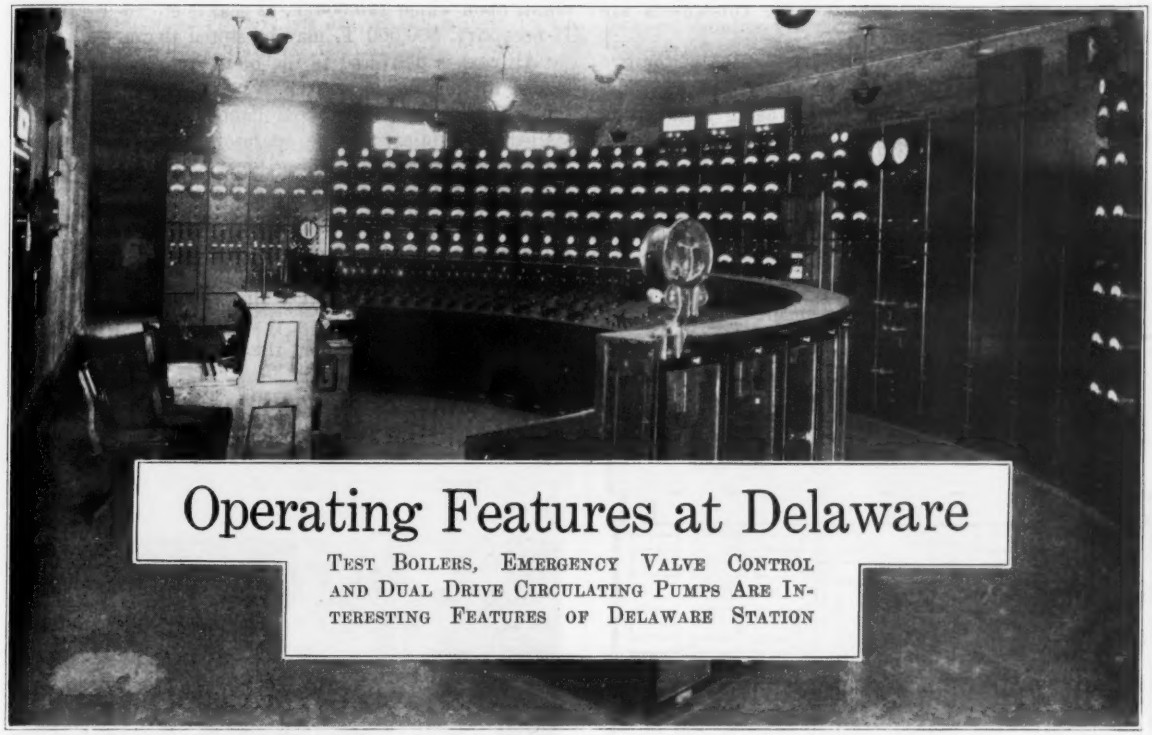
Run a straight line through the 84, column A, and the 30 in column B and locate the intersection with column C. By means of the eye, follow the radiating "guide lines" to column D, locating a second point of intersection. From this latter intersection run through the 142, column E, and locate the point of intersection in column F. Then from this point run over to the 84, column H, and the intersection in column G will be found to be close to 1050 gal., which is the answer.



CONTENTS OF TANKS IN GALLONS IS COMPUTED BY THIS CHART

Since column E takes care of lengths of tanks up to 100,000 in. it is plain that not only will this chart compute tanks but it will include long pipes whenever it is desired to compute either the full capacity of such pipes or their partial capacity: 100,000 in. is equal to 8333⅓ ft. It is also applicable to tanks with vertical axes in which case h is equal to D and L is the depth of the liquid in the tank.

Copyright, 1924, by W. F. Schaphorst



Operating Features at Delaware

TEST BOILERS, EMERGENCY VALVE CONTROL AND DUAL DRIVE CIRCULATING PUMPS ARE INTERESTING FEATURES OF DELAWARE STATION

SOME FOUR AND ONE-HALF years ago, in September, 1919, to be exact, construction work was started on a large central power station in Philadelphia for the Philadelphia Electric Co. This station, now known as Delaware station, was built to take care of the steadily increasing load in and around Philadelphia, particularly in that section of the city known as Kensington near which the station site was located. It was evident from a careful study of load conditions that the power load in this district would continue to increase at a rapid rate for some years to come, so in planning the ultimate station it was necessary to keep this in mind. An ultimate capacity of 180,000 kw. was decided upon—this limit being fixed more by the ground area available than the expected load.

Two of the six 30,000-kw. units were included in the initial installation, the first unit going on the line in Oct. 1920, just 13 mo. after construction work was started. Since that time three other units have been added as load conditions demanded, and at the present time the sixth and last machine is being put in place. Thus in less than five years, the ultimate capacity of the plant has been attained.

Ever since the first unit was completed, this station has held an enviable reputation for good engineering, both as regards its constructional features and its operating performance. Its symmetrical arrangement, its fine architectural design and its high economy are a few of the outstanding features which have made Delaware one of the best known stations in the East. As to the operating methods, it is significant that when the prime movers committee of the N. E. L. A. recently began work on a proposed code for standardizing operating methods in power stations, they selected the operating methods used at Delaware as the basis for their studies.

Before proceeding with a discussion of the operating methods, it may be well to present briefly a description of the important constructional features.

A plan of the station showing the general arrangement of the component parts is shown in Fig. 1. There are, as may be noted, two boiler houses located symmetrically with respect to the turbine hall with a storage building between the boiler houses. The storage building also contains the machine and repair shops. The electrical bay is placed parallel to the turbine room to simplify the running of conductors between the generators and the switches.

Each boiler house contains twelve 1500-hp. Stirling boilers equipped with underfeed stokers. Forced draft is supplied to the furnaces by 80,000-cu. ft. per min. fans, one for each boiler. Induced draft is obtained by means of two fans for each boiler, each fan having a capacity of 75,000 cu. ft. per min. The forced draft fans are located in the basement underneath the boilers while the two induced draft fans for each boiler are installed in a common breeching above the boilers. A damper is provided so that either fan may be shunted out of the draft circuit.

Electric current is generated by six 30,000-kw. turbogenerators, five of which are General Electric Co. machines, while the sixth now being installed is a Westinghouse unit. These machines are placed crosswise of the turbine room with their steam ends towards the boiler room and the electrical ends towards the switch house. Each machine exhausts into a 50,000-sq. ft. surface condenser served by two 37,500-gal. circulating pumps. To prevent the condensation of moisture from the air upon the exterior surfaces of the condenser pumps and connected cold water piping, all these surfaces are covered with ground cork. This is an effective method for keeping these surfaces dry. Condensate pumps and air pumps

are also installed in duplicate and the condensers are fitted with high water alarms.

To further insure continuity of service, each of the two circulating pumps serving each condenser has an independent intake, the circulating system being installed in duplicate with the exception of the discharge tunnels, which are so arranged that a separate tunnel serves each three units.

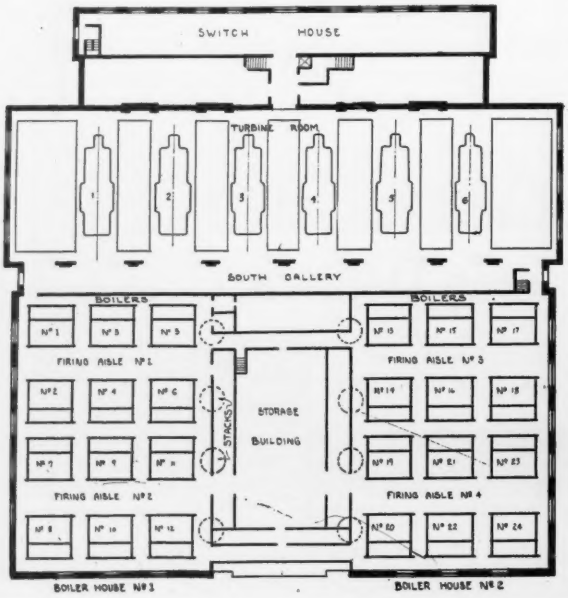


FIG. 1. THE SYMMETRICAL ARRANGEMENT OF DELAWARE IS ONE OF ITS OUTSTANDING FEATURES

On the electrical side of the station again, we find all the important equipment installed in duplicate. Two sets of main busses are provided. Generator leads are arranged so that they may feed into either bus and the feeders may feed from either bus.

Control of the station is effected from a main control room located between the turbine room and the switchhouse.

Operation

By far the largest item in the cost of power produced in a steam generating plant is fuel. Fuel must be obtained as cheaply and burned as economically as possible.

Where the plant is situated close to the mines, it is economical to purchase a low grade, cheap fuel but where the plant is situated a long distance from the mines it is economical to purchase a high grade, high priced fuel since the freight charges are a large percentage of the cost of fuel delivered and are the same per ton for low grade as for high grade fuel, it is evident that a low grade fuel will be expensive in the latter case.

Where the plant is situated some distance from the mines, it is necessary to provide ample storage so that interruptions to traffic due to weather conditions, etc., will not cripple the plant.

At Delaware, the limited amount of ground area available did not permit an adequate coal storage to be maintained in the immediate vicinity of the plant. To insure an adequate supply of fuel at all times, the company purchased an island known as Petty's Island in the Delaware River about three quarters of a mile from the plant, upon which 120,000 T. of coal is stored at all times. If necessary, 500,000 T. may be stored there.

All coal is delivered to the plant by barges and is unloaded by hoisting apparatus in a coal tower on a pier at the station. The entire coal handling equipment is installed in duplicate. One operator in the coal tower is able to operate the unloading hoist and transfer the coal from the barge to the receiving hopper at the top of the tower. This operator is stationed in a compartment which gives him a view of the barge and the hoisting equipment on the exterior. By means of levers and foot pedals he drops the bucket to the barge, fills it, hoists it to the top of the tower, and discharges it into a receiving hopper. Operating in this manner, the apparatus will handle a maximum of 240 T. per hr.

In the tower on the floor below the hoisting operator's station, another man inspects the coal as it travels before him on a belt delivering to the crusher. He removes any foreign material which might damage the crusher,

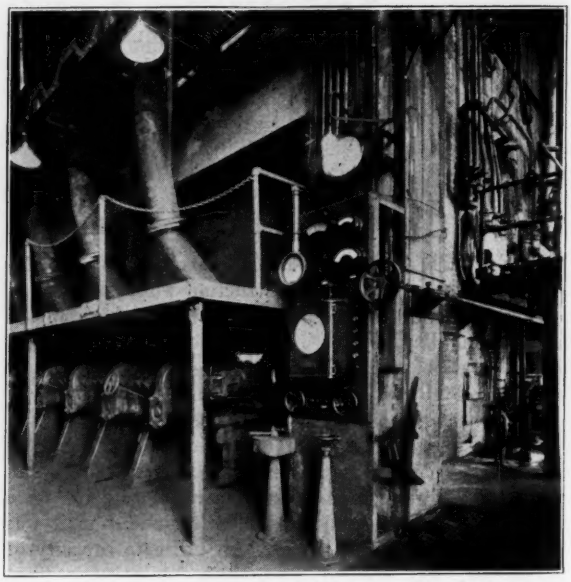


FIG. 2. BOILER PERFORMANCE IS DETERMINED BY MEANS OF ONE TEST BOILER FOR EACH GROUP OF SIX

From the tower the coal is conveyed by means of belts to the top of the boiler houses where other conveyors deliver it to the bunkers over the boilers. Pipes extending from the bottom of the bunkers to the stoker hoppers are the final link in the coal delivery.

All coal handling equipment is subject to practically continuous inspection and maintenance, and an adequate supply of spare parts such as sprockets, cable, belting, etc., is kept on hand.

How the Coal Consumption is Determined

To determine the station coal consumption, use is made of test boilers, one of which is provided for each group of six units. These test boilers are, of course, exact duplicates of the boilers in their group; they are provided with automatic dumping scales which record every 150 lb. of coal delivered to the stoker hoppers. The stoker on the test boiler, as well as those on all the other boilers, is fitted with a revolution counter. By multiplying the

total number of dumps by 150 and then dividing by the number of stoker revolutions, the number of pounds of coal per revolution is obtained. This average figure is then applied to all other boilers in the group. In this manner an accurate determination of the coal consumption is secured, and the necessity for installing coal scales on each boiler is obviated.

Boiler Operation

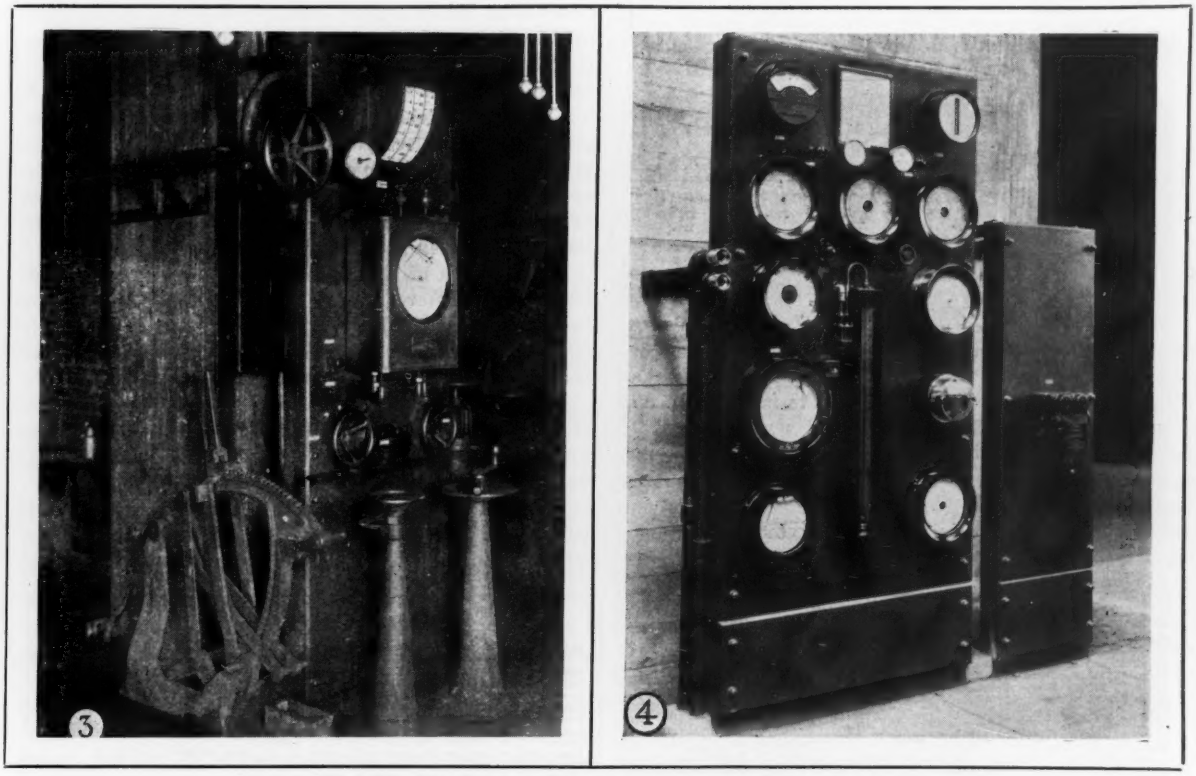
For determining boiler performance, each boiler is provided with its own instrument and control board, which centralizes the entire control for the boiler at one point. These control boards are located on the boiler room floor, the boards for each group of four boilers being located close to each other so that one man can easily take care of the group.

Each board is divided with an indicating gage which shows the wind box pressure, the firebox pressure and the stoker speed, a recording boiler meter, thermo couple receptacles, damper position indicator, damper control button and the controls for the induced draft fans. A hand wheel and a controller immediately in front of the boiler control board control the forced draft and the stoker motors.

The method of controlling the dampers is of interest. These are hand controlled but operated by electric motors remote controlled from the boiler panel. If the operator wishes to alter the position of the damper, he pulls a control button on the board which sets the damper motor in operation. As long as he keeps his hand on the control button, the damper will move but as soon as he releases it, the damper stops. An indicator on the panel indicates the position of the damper with respect to the open or closed position at all times.

The thermo couple receptacles on the control board are used in determining the temperature of the steam in the superheaters. Once a week a potentiometer is connected into these receptacles and the temperature taken. The readings so obtained indicate the condition of the exterior superheater surfaces.

Feed water to the boilers is controlled by pump governors on the boiler feed pumps and by feed water regulators on the boilers.



FIGS. 3 AND 4. BOILER AND TURBINE CONTROL BOARDS

Fig. 3. Each boiler has its individual control panel. The two pedestal type control wheels are for the forced draft and stoker motors. Fig. 4. One of the turbine control panels showing the Dean emergency quick closing valve control box at the right.

In order to insure freedom from shutdown due to failure of the water supply, Delaware station has available four different sources of feed water supply. Normally, the condensate from the main condensers is used but if this fails, either filtered or unfiltered river water can be supplied or, if the emergency should arise that all of these sources fail, city water may be admitted to the boilers.

For make-up purposes, filtered river water is used. This water is pumped from the river through sand filters, through the make-up meter, and then to the feed water heater surge tanks. No water treating system is necessary, as the amount of make-up water required is exceedingly small and the river water contains little scale forming material.

It is necessary, however, to remove the oxygen content of the feed water as this leads to pitting of the economizer surfaces. The water is, therefore, passed through

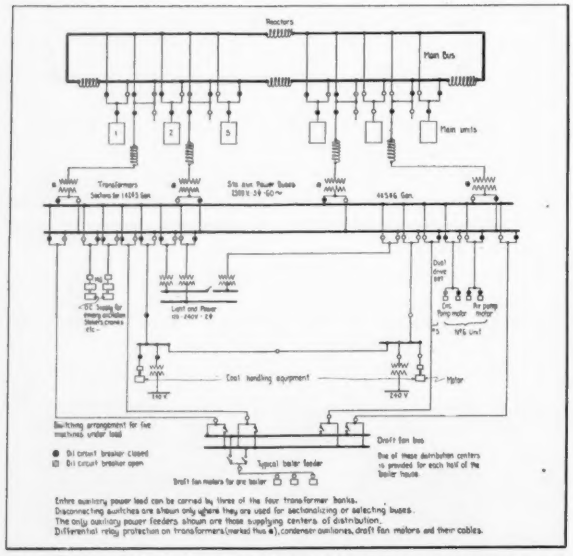

Reactors
Main Bus
Main units
Transformers
Sta ion Power Buses
44546 Gen.
Dust driers part
Exc. Turbo-motor
Air pump motor
Unit
Coal handling equipment
Motor
Switching arrangement for five machines under load
Oil circuit breaker closed
Oil circuit breaker open
Draft fan bus
Typical boiler feeder
Draft fan motors for one boiler
Entire auxiliary power load can be carried by three of the four transformer banks.
Disconnecting switches are shown only where they are used for sectionalizing or selecting buses.
The only auxiliary power feeders shown are those supplying centers of distribution.
Differential relay protection on transformers (marked thus ●), condenser auxiliaries, draft fan motors and their cables.

FIG. 5. LAYOUT OF THE AUXILIARY POWER SYSTEM AT DELAWARE

deaerators, one of which is installed for each open feed water heater.

Boiler feed pumps are all turbine driven. This is true not only at Delaware but in all other stations of the Philadelphia Electric Co. as well. This is standard practice with the company and is based upon the fact that in case of serious disturbance in the electrical system, the boiler feed pumps will not be affected. Furthermore, a certain amount of exhaust steam is necessary in order to heat the feed water. The boiler feed pump turbines together with certain other steam driven auxiliaries to be mentioned later, furnish this steam.

Boiler feed water is tested for oxygen content every day. If too much oxygen is present, an examination is made of the pump and associated piping to determine where the air leaks in. This is an important part of the station routine.

Water in the boilers is tested for concentration once a day and the boilers are blown down in accordance with the indications obtained from the tests.

Emergency Valve Control

All main steam valves on the boilers and in the headers are electrically operated by the Payne Dean system of control. These valves are operated from a station in the immediate vicinity of the valve itself and in addition may be closed from the emergency control board in a special room in the basement of the boiler house. This emergency control board is a vertical slate board on which the high pressure steam header system is laid out with mimic pipe lines. The control switches which operate the electrically operated valves are placed at the proper places in the mimic pipe system so that one can tell at a glance which switches are open and which are closed. The control boxes are provided with red and green lights—the red indicating that the switch is open and the green that it is closed.

In case one of the 18-in. main steam headers should burst, or in the event of a similar accident, the operators in making their escape from the boiler room can enter the emergency control room and close whichever valves are necessary to isolate the ruptured line.

One of these emergency control boards is provided for each boiler room. The rooms in which they are placed are located so as to be accessible from the outside of the building.

In addition to the electrically operated valves on the boilers and headers, there is also an electrically operated quick closing throttle valve in each main steam connec-

WEEKLY INSPECTION SCHEDULE - ELECTRICAL APPARATUS

Shift — Saturday April 12th, 1924 — 79th Week

Overhaul and clean coal tower unloading control and motors
Clean "A"I.D.F.motors #1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18
Clean "B"I.D.F.motors 1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18
Clean F.D.F. motors 1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18
Clean stoker motors 1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18
Clean S.M. controllers 1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18
Clean boiler control panels 1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18
Clean I.D.F.rotor resistance1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18
Clean I.F.contractor panels 1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18
Clean damper motors & limit switches 1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16, 17,18
Clean F.F.rotor resistance 1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18
Examine and renew field and exciter brushes 1,2,3,4,5
Clean generator field resistance1,2,3,4,5
Clean exciter field resistance 1,2,3,4,5
Clean & lubricate gov. motor and test limit switches 1,2,3,4,5
Clean and inspect coal scale motors - boilers 1,7,17
Clean locomotive battery charging set, switchboard and room
Clean and inspect generator air washers 1,2,3,4,5
Clean & inspect generator air washer motors and pumps 1,2,3,4,5
Clean condensate motors 1,2,3,4,5
Clean air pump motors 1,2,3,4,5
Clean cir. pump motors 1-A,1-B,2-A,2-B,3-A,3-B,4-A,4-B,5-A,5-B
Clean & inspect cir.pump contactors 1-A1-B, 2-A,2-B,3-A,3-B,4-A,4-B,5-A5-B
Clean air compressor motors 1,2,3
Clean transformer blower motors and fans 1,2,3
Clean transf.blower room and air duct and inspect damper mechanism
Clean control motor generator sets 1,2
Clean battery room and add water
Equalizing charge on excitation battery
Clean & inspect boiler house vent.fan motors 1,2,3,4
Clean and inspect #1,2,3 motor generator sets
Make standard electrical test on 4-B & 5-B circ. pump motors

Clean battery room and make overcharge of control battery
Equalising charge to locomotive batteries #1,2
Clean motors of ice plant
Inspect starting equipment of ice plant
Clean motor of river water pump
Clean motor of fire pump
Inspect starting panel and clean motors of city water pumps 1,2
Clean control board and sweep fan bus room
Clean blower motor over range in restaurant

Clean motor and examine float switch of drip pump
Clean Dean Control motors on steam headers #1,2,3 & 10" valve on 7,8,10 & 12 boilers
General inspection of fire systems
Clean transformer banks 1,2,4,6,7
Inspect compensator on oil pump motors 1,2
Inspect compensator on auxiliary oil pump motor
Inspect compensator on locomotive charging set
Inspect compensator on eliminator motors 1,2,3
Clean one pair 13,000-V feeder compartments
Change oil in coal scale motors 1,7,17

WEEKLY INSPECTION SCHEDULE -

Shift — Saturday April 12th, 1924 — 16th Week

Change oil & clean strainers - turbines 1,2,3,4,5
Underspeed test ..... - " 1,2,3,4,5
Inspect governor oil spray nozzles" 1,2,3,4,5
Change oil & examine bearings-B.F.P. - 1,2,3,4,5,6,9,10,11
Change oil & examine bearings-R.W.pumps #1,2 and Turbine #2
Change oil & examine bearings-Fire pumps 1,2 and Turbine #1
Change oil & examine bearings-City Water Pumps #1,2
Change oil & examine bearings-drip pumps #1,2 & sump pumps #1,2,3,4
Change oil & examine bearings-deaerator pumps #1,2
Change oil & clean crank case-air compressors #1,2
Change oil in ventilating fans-boiler house roof #1,2,3,4
Change oil F.D.F. bearings 1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18
Change oil "A"I.D.F.bearings 1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18
Change oil "B"I.D.F.bearings 1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18
Change oil and examine bearings-sweet water pumps #1,2
Make speed test & set gov. 10% high-Circ.pump 1-A,2-A,3-A,4-B,5-B
Make speed test & set gov. 10% high-Air pump 1-A,2-A,3-A,4-B,5-B
Make speed test & set gov. 10% high-Wet pump 1-A,2-A,3-A,4-B,5-B
Make speed test & set gov. 10% high-River Water Pump #2 & Fire Pump #1
Change oil & examine bearings-screen house pumps #1,2
Clean & oil gears on 42" G.V.-Cir.Pump 1-A,1-B,2-A,2-B,3-A,3-B,4-A,4-B,5-A,5-B
Inspect and operate 16" quick stop valves-1,2,3,4,5
Clean control valve stems & grease guides for cross head on units 1,2,3,4,5
Open,wash out and inspect filters 1,2,3,4,5
Inspect and clean gov. trans. roller bearings - turbines 4,5,6
Blow out oil line connection on #1 bearings on turbines 3,4,5

Make overspeed tests on turbines 1,2,3
Clean oil coolers if necessary - turbines 1,2,3
Change oil & inspect bearings air pumps 1-A,1-B,2-A,2-B,3-A,3-B
Change oil in gear case & clean oil cooler,air pumps 1-A,2-A,3-A
Change oil & inspect bearings-wet pumps 1-A,2-A,1-B,2-B,3-A,3-B
Inspect interior of deaerators 1,2,3
Change drinking water
Inspect all couplings on auxiliaries of turbines 1,2,3
Check quantity of water used on low pressure scale-turbines 1,2,4,5

Inspect reduction gears on circulating pumps 1-A,2-A,3-A
Inspect reduction gears on air pumps 1-A,2-A,3-A

FIG. 6. INSPECTION SCHEDULES OF THIS TYPE ARE SENT TO THE OPERATORS EVERY WEEK

tion between the turbines and the boiler room. These valves are placed just inside the boiler room wall and can be operated either from the boiler room or from the turbine operating board.

With any electric control system of this type one of most important factors in its operation is the periodic testing of the valves. To insure their positive action at Delaware, these valves are operated each week, once from the turbine room control station, and once from the control box in the boiler room.

Boiler Maintenance

Boilers are shut down for inspection and repair, once every eight weeks. At such times they are generally out of service for 4 or 5 days depending upon the extent of the repairs, and are given a thorough cleaning and overhauling. The heating surfaces of the boilers and superheaters are inspected for scale and pitting, the brick work is repaired, safety valves are thoroughly inspected, etc. If no serious trouble is found the unit is closed up and is generally on the line within five days after it was closed down. When running, the safety valves are tested by hand once a week.

The boilers are also given a yearly inspection, at which time an hydrostatic test is applied.

Stokers are inspected and repaired at the same time that the boiler is closed down, and in addition, are examined every week end in order to anticipate any serious breakage.

All instruments in the station are in charge of a special man who devotes his entire time to their maintenance. He is provided with suitable standards with which to check recording and indicating instruments, and is competent to keep them in repair.

Turbine Room Operating Features

One of the most interesting features in the operation of Delaware station is the dual drive on one of the two circulating pumps serving each condenser. One of these pumps is motor driven while the other is driven by a steam turbine at one end and by a 2300-v. slip ring induction motor at the other end. By the use of this system of drive two results are obtained; first, a flexible unit is available which by varying the load on the turbine drive will supply the required heat variation for maintaining a practically constant feed water temperature. Second, in case of trouble with either the steam supply or the electric service, the opposite drive will automatically pick up the load and thus keep the condenser water in circulation. The other circulating pump, which is provided with a motor drive only, is used as a reserve unit or in case it is desirable to operate two circulating pumps, at a time when high circulating water temperatures occur.

This dual drive is controlled automatically by means of the feed water temperature. In the feed water heater is located a resistance element which is connected to a relay which controls a small motor operating the governor of the circulating pump turbine. If the temperature rises above normal, the current through the resistance element decreases slightly, causing the motor to decrease the governor setting on the pump turbine slightly. This results in a reduction in the amount of exhaust steam supplied to the heater and the feed water temperature is lowered. At the same instant, the induction motor automatically picks up the load so as to maintain the pump speed practically constant.

In working out the heat balance of the station, the factor of reliability was considered of even somewhat greater importance than that of heat economy. It has always been considered by the company that the small comparative cost of duplicating the main generator auxiliaries is fully warranted in view of the resulting ability to keep a large unit on the line in case of failure of any of the auxiliaries connected with the unit. Duplicate auxiliaries were therefore installed. The next step was the method of driving them. Enough steam driven auxiliaries were therefore installed to furnish the required amount of exhaust steam necessary to heat the feed water under varying conditions of vacuum.

Each of the six main generating units has its individual control panel. These are located near their respective turbines and contain the necessary indicating and

FIG. 7. WHEN ALL AUXILIARIES ARE REPORTED RUNNING THE TURBINE ENGINEER OPENS THE THROTTLE SLIGHTLY

recording meters as well as a signalling system to the main control room. A view of one of these panels is shown in Fig. 4. The small panel at the right has mounted on it the control box for the electrically operated quick closing valve in the turbine header.

In addition to the shift superintendent of the station, there is an engineer on the turbine floor and an assistant on the auxiliary floor for each shift. The shift superintendent has no watch nor fixed post as his duties are in connection with the plant as a whole. The turbine engineer is in direct charge of all turbo generators and associated equipment on the turbine floor. The engineer on the auxiliary floor has complete charge of auxiliaries.

The load on the station at various hours is assigned by the system load dispatcher and the station is also notified as to how much reserve capacity is to be carried. The

station operator consults with the shift superintendent as to what machines are to be operated on this schedule.

Approximately an hour before the machine is to carry full load, the chief operator in the control room signals the engineer who sees that the auxiliaries are started. When the auxiliaries are all reported running, the turbine engineer opens the throttle slightly and the machine is allowed to revolve slowly and warm up. This continues for approximately one-half hour, after which the signal "full speed" is sent to the turbine engineer. After the machine has come up to full speed and is under control of the governor, the engineer signals "load" and the switchboard operator synchronizes and loads the unit.

The signal system between the chief operator and the turbine engineer is interesting and somewhat resembles the engine room telegraph used aboard ships. As each order is given, a reply must be obtained from the engineer to indicate that it has been executed.

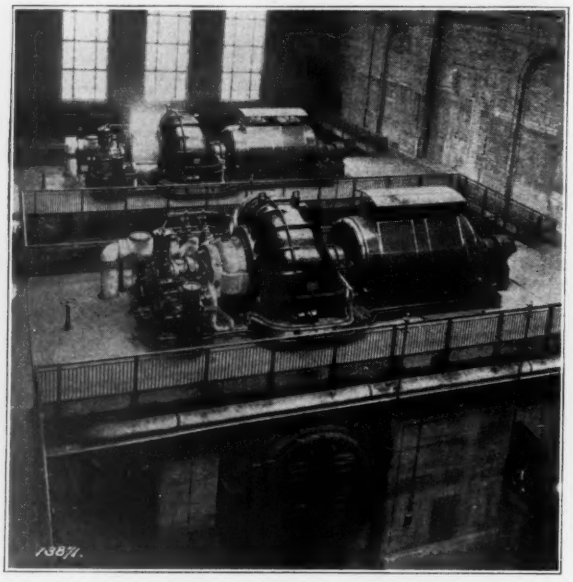


FIG. 8. TWO OF THE SIX TURBO GENERATING UNITS

The signal system is only for communication between the turbine room and the control room. The boiler room force is not interested, except in knowing the total load the station is carrying. To this effect an illuminated kilowatt meter is installed in a conspicuous place in each boiler room. This meter indicates the station load in kilowatts at all times.

Inspection and Maintenance

Inspection and overhauling of equipment in the station is taken care of by a well planned system which provides for complete inspection of certain pieces of apparatus at regular intervals. A complete list of all the equipment is in the hands of the chief engineer. Each week certain apparatus is selected from this list and entered upon schedule sheets which are sent to all departments. A certain sheet, for instance, will have included on it boiler feed pump No. 6 under which instructions are given to inspect the bearings, renew packing, examine throttle valve, check action of pump governor, etc. Typical examples of these schedules are shown in Fig. 6. The operators receiving these sheets must carry out the instructions contained thereon and note that they have been complied with or state the reasons for not doing so.

Each week new apparatus is selected until everything in the station has received attention. Then the process is repeated. Under this same plan the steam and power consumption of all equipment is redetermined from time to time. The heat balance of the station is worked out every day from the records, charts and tabulated readings of instruments taken by the operators.

All men on duty at the station work six days a week. This is made possible by means of an extra shift.

In concluding this article we wish to extend credit to H. P. Liversidge, assistant chief engineer of the company, N. E. Funk of the operating department and to Mr. Taylor, superintendent of Delaware Station, for courtesies extended during the preparation of this article.

Operation of Steam Jet Ash Conveyors

Before a steam jet ash conveyor is started up, make all necessary preliminary arrangements for quick disposal of the ash. If clinkers are present, they should be broken up to a size that will readily pass the intake opening before the conveyor is started in operation, or the steam turned on. No water should be allowed to accumulate in your conveyor pipe line. If water is in this line, ash will plug up the line. Always keep the conveyor pipe line dry.

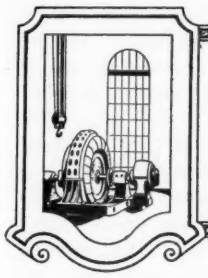
Drain all condensation from the steam line thoroughly. Dry steam is absolutely necessary for this type of conveyor. Open throttle valve for steam supply line to nozzle full wide. After conveyor is in full operation, immediately begin to feed the ashes. Start feeding ashes at intake nearest to steam unit and work back from that point.

Feed dry ashes only. The system will not work satisfactorily on wet or damp ashes. If ashes are wet or damp, do not put them into the conveyor. Keep feeding the ashes steadily without overloading the conveyor. Do not feed a large quantity of ash at one time, but arrange for a steady stream of ash into the conveyor which will be well within the capacity of same at the point of feeding. The action of the conveyor is fast close to the steam jet and slows down as the distance from the steam jet increases. Govern the feeding by the sound. When the suction is loud, the conveyor is empty and when the noise dies down, the conveyor is being overloaded. Keep the sound loud enough to give maximum capacity without overloading.

Shut the throttle valve tightly immediately the conveyor pipe is emptied of ashes. Under no circumstances allow the conveyor to run empty. If this instruction is neglected, operating cost of the conveyor is much increased by waste of steam.

An opening the full size of the internal diameter of the pipe should always be left at the end of the suction line farthest from the steam unit as an air supply opening. Inspect the conveyor once each month for wear and leaks. The conveyor will not operate satisfactorily with leaky flange joints or worn-out parts since it must be kept tight to maintain suction.

The nozzles, supplied with the conveyor are the right size to operate it at your regular boiler pressure. These nozzles will not operate the conveyor satisfactorily at less than regular steam pressure. The conveyor can be satisfactorily operated at almost any steam pressure if the nozzles are properly adjusted.



ELECTRICAL MACHINERY FOR LIGHT AND POWER

Load Dispatching System of P. G. & L. Co.

CONTROL OF WHAT IS PERHAPS THE LARGEST ELECTRIC POWER AND TRANSMISSION SYSTEM IN THE WEST CENTRALIZED AT ONE POINT. BY C. W. GEIGER

IN THE OPERATION of any electrical system the objects first to be considered are continuity of service and regulation of voltage. With a system having but a few sources of supply and these located near together, the problem is a comparatively simple one but as the number of generating stations is increased and lines are added until they form a network extending for hundreds of miles, the problem becomes more and more complicated. The system of the Pacific Gas and Electric Co. is unique in that it has a greater mileage of high voltage lines receiving power from a larger number of sources than any other system in the world. Not only do the 26 hydroelectric powerhouses of the company and its leased properties, aggregating an installed capacity of approximately 314,000 kw. or about 415,000 hp., all operate in parallel but they are interconnected with and receive power from eight other operating companies, besides being continuously in parallel with the steam-electric generating plants in San Francisco, Oakland and Sacramento.

Supplied from this super power system are 259 substations all owned by the company with a total transformer capacity of 774,829 kw. Through these substations some 312,000 consumers are supplied with electric power and light. These consumers are located in 89 incorporated cities, 142 towns and villages while the rural sections served aggregate 37,000 sq. mi.

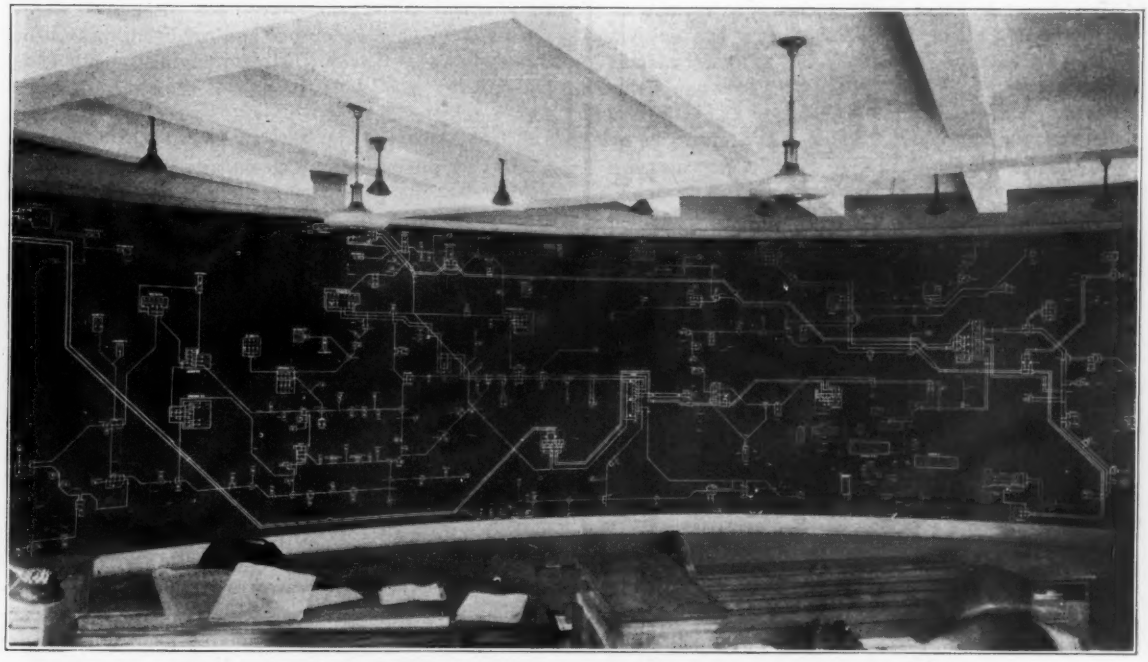


FIG. 1. THE LOAD DISPATCHER'S OPERATING BOARD

This board is built in the form of an arc of about 29 ft. radius and is 10 ft. high by 40 ft. long. It is made of No. 12 gage sheet iron bolted to an I-beam frame. Switches are represented by small colored glass lenses lighted from behind.

CONTROL CENTRALIZED IN ONE OFFICE

In order that a system of this magnitude and complexity may operate successfully it is essential that the control of the component units be centralized. Particularly in times of emergency, when storms or other troubles render one or more lines inoperative, it is necessary that the load be readjusted and redistributed among the re-

maining power plants on the system in order to maintain continuity of service.

With regard to the handling of the load and the regulation of voltage on the system of the Pacific Gas and Electric Co. there is but one person in authority. W. D. Skinner, chief load dispatcher with headquarters in the company's building in Oakland directs the operation of each one of the electric generating stations scattered throughout the state. At the present time, there are eight men who devote all their time to the operation of

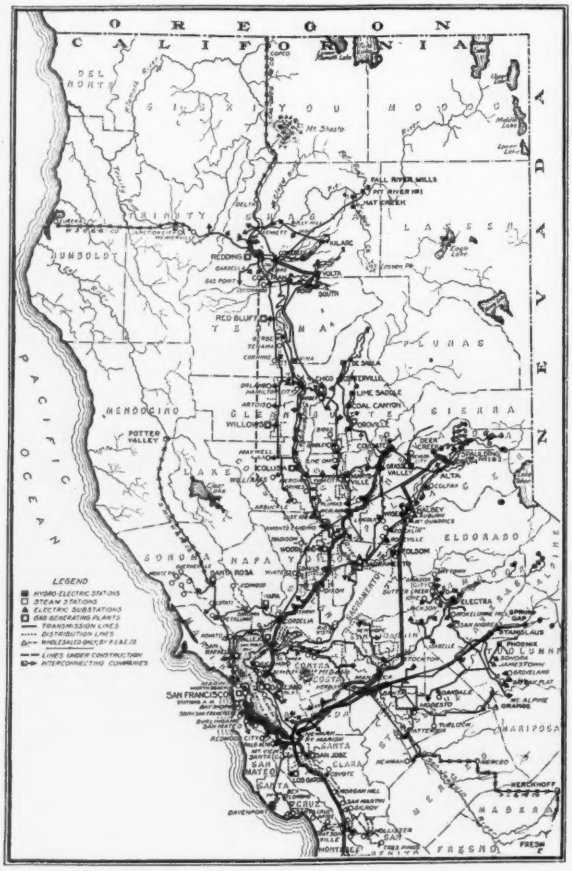


FIG. 2. MAP SHOWING THE TRANSMISSION AND DISTRIBUTING SYSTEM OF THE PACIFIC GAS AND ELECTRIC CO.

the system and the necessary routine for which the office is held responsible.

Telephone System an Important Link in Load Dispatching System

The factor of greatest importance in the operation of any system of this type is that of maintaining perfect communication between all components parts of the system at all times. This is provided for in a highly perfected telephone system installed between the load dispatcher's office and the principle power houses and switching stations. By means of this telephone system the load dispatcher is able to keep in close touch with the constantly varying demands of the consumers and with the available capacity of the various stations in the system.

A private telephone exchange comprised of two modern P. B. X. boards connected in multiple to allow two men to work at the same time is installed at the Oakland office. Each of these boards carries 14 trunk lines and is capable of handling several hundred calls in an 8 hr. shift, besides providing for instant control by the load dispatcher in emergency of any telephone line needed for operation.

To avoid congestion and minimize the issuance of orders the system is divided into 26 switching centers each reporting to and directed by the central load dispatcher. In the event of unusual trouble or when the routine system of switching is inadequate, the load dispatcher takes direct command and issues the orders necessary for the resumption of service. A total shut-down of the system has never occurred.

Another, and by no means unimportant, function of the load dispatcher more clearly relates to management than to the superpower system. From every point throughout the system of importance and of use in operation or in the perfection of service is collected and passed on through the switching centers to the central load dispatcher's office where it is edited, boiled down and summarized into a daily service report covering the 24-hr. period ending at midnight, and placed on the desks of the executive and management officers at 8:30 on the following morning. Each executive has, therefore, upon his arrival a concise report of power-plant output and condition, peak demand, water storage, canal flow, stream gagings, depth of snow, and weather conditions throughout the system.

Carrier Current System in Continuous Use

During the past year the company has entered the radio field and at the present time there is in continuous operation a system of directed radio or wired wireless connecting Pit No. 1 power house with the Vaca-Dixon substation. This new means of communication has proven itself to be highly satisfactory from an operating standpoint, and the load and voltage regulation, switching, etc., on the Pit River development is handled entirely by radio. Another transmission and receiving station is in process of installation at the Claremont sub-station and when completed will be controlled directly from the load dispatcher's office, thus eliminating the relaying of messages through Vaca-Dixon. Further development along this line is contemplated if these initial installations continue to give satisfaction and a long step toward perfection in the dispatcher's communication system has been taken. The transmitter used is similar in many respects to that used by several of the large high-powered broadcasting stations. The accompanying photo was taken during the initial tests and installation, since which some refinements have been made. The right-hand telephone shown in the photo belongs to the carrier current set. On the wall just back of the transmitter can be seen a pair of little tumbler switches; one switch is for sending or receiving, the other for calling or talking. A third switch not so clearly seen in the photo is for the head phones or the loud speaker.

When the operator desires to talk to Vaca, he takes the receiver off the hook, which automatically starts up a small motor generator set to furnish power for the four 250-w. "Radiotron" tubes shown suspended on the framework of the transmitter. The tumbler switch is then thrown to the "send" position and the tubes begin to oscillate and send out a carrier wave. The other tumbler switch is then thrown to the "call" position. This completes the circuit through the transmitter shown mounted

in the horn of the loud speaker, and it immediately begins to howl in the same manner that the telephone will howl when one places the receiver against the transmitter. This howl is transmitted to Vaca and received in the loud speaker as a shrill whistle. The tumbler switch is then thrown to the "talk" position and conversation proceeds.

The modulated carrier wave is transferred to the 220,000-v. transmission line via the antenna located directly underneath and is transmitted to Vaca, where it "hops off" onto the Vaca antenna and is led into the substation. When the operator at Pit has finished what he has to say, he throws his "send-receive" switch to the "receive" position. This connects the radio receiver shown in the bottom part of the transmitter to the antenna and the answer from Vaca is received either in the telephone receiver or the loud speaker, as desired.

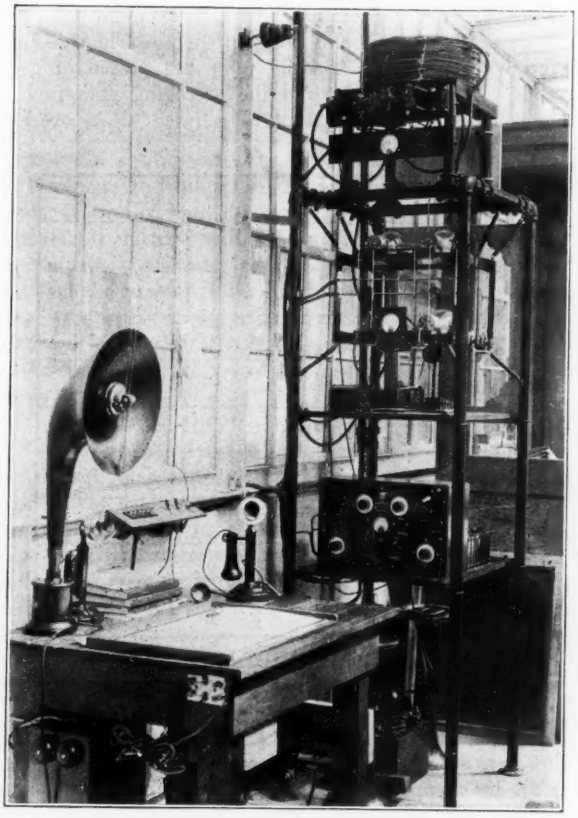


FIG. 3. THERE IS IN CONTINUOUS OPERATION A HIGHLY SATISFACTORY SYSTEM OF CARRIER CURRENT TELEPHONY

Vaca substation is located about 60 mi. from Oakland and is connected to the load dispatcher office by land telephone lines. Messages from Pit have to be received by the operator at Vaca and relayed to the dispatcher over the land wires.

Dispatcher's Operating Board Made of Sheet Metal

What is probably the most radical change in dispatching equipment that has been made since the founding of the office is that made in the construction of the dummy switchboard erected in the Seventeenth and Clay office. Heretofore all the boards erected have been built up of redwood boards, glued and pinned together and mounted on special sliding supports to take care of expansion and contraction. The wooden boards have always given some trouble from cracking and the scaling of paint, etc., so it was decided to construct a metal board and eliminate in one stroke all these difficulties. The dummy switchboard, as it now stands completed, is made up of sheets of No. 12 gage sheet iron, bolted to an I-beam frame which is securely fastened to floor and ceiling. The board is built in the form of an arc of about 29 ft. radius and is 10 ft. high by 40 ft. long. All joints were filled with special metal putty and the surface covered with a gun metal colored paint, eliminating all traces of joints and giving the finished board the appearance of a solid sheet of metal of neutral tint, furnishing an ideal surface for the application of vari-colored striping to represent transmission and distribution lines of different voltages. Switches are represented by small colored glass bulls-eyes, set in holes drilled in the metal plate and lighted from behind to render them easily distinguishable. The new board has proven itself to be extremely satisfactory from the dispatcher's standpoint.

The dispatching desks now in use are built so as to combine convenience with compactness, and enable the dispatchers to work at high speed with a minimum of lost motion. A diagram of the entire system, showing transmission and distribution lines, power houses and sub-stations with switches, generators, transformers, etc., indicated and described, is mounted on a system of motor driven rollers at the front of the desk in such a manner as to enable the dispatcher to consult any portion of the diagram without effort whenever necessary. The telephone exchange boards are set at the dispatcher's left hand and fitted into the operating desks in such a manner as to make it unnecessary for him to move from his seat in the ordinary course of his work. Filing cabinets, map cases, etc., are arranged with an eye to accessibility and convenience, and, above all, the space allotted for the dispatching room is commodious enough to give plenty of "elbow room."

In order to maintain the commutator in proper condition and reduce the wear to a minimum, it is vitally necessary that a proper adjustment of the brushes be secured. They should work absolutely free from sparks. Any sparking whatever indicates a bad condition of the commutators or defective adjustment of the brushes.

The end of the brushes should be carefully beveled so as to conform accurately with the surface of the commutator. The brush should bear lightly upon the commutator and every part of the beveled end should rest upon it. The pressure should be just sufficient to insure good contact and avoid all cutting and scratching.

One of the worst causes of sparking is the lack of pressure of the brush, caused by improper setting of the brush-holder stud or by allowing a brush to wear too short. To maintain the proper angle, the brush as it wears must be pushed forward in the holder from time to time.

A dynamo in operation with sparking brushes is prima facie evidence of carelessness or ignorance on the part of the attendant, and such a condition of affairs should not be tolerated under any circumstances.

To find the diameter of a pump cylinder to move a given quantity of water per minute (100 ft. of piston being the standard of speed), divide the number of gallons by 4, then extract the square root, and the product will be the diameter in inches of the pump cylinder.

Pointers on the Care of Electrical Equipment

CAREFUL OBSERVATION OF EQUIPMENT AND A KNOWLEDGE OF DISTURBING CONDITIONS ENABLES OPERATOR TO ANTICIPATE SERIOUS TROUBLE

IN CONSIDERING the care and repair of electrical equipment from the view point of the power plant operator, we are concerned mainly with methods of maintaining the machinery in his care in the best operating condition and in the prevention of serious damage by the correct diagnosis of trouble at the earliest possible moment. Once a machine burns out, it is usually not up to the plant operator to repair the damage, unless of course it happens to be a small machine which he can easily

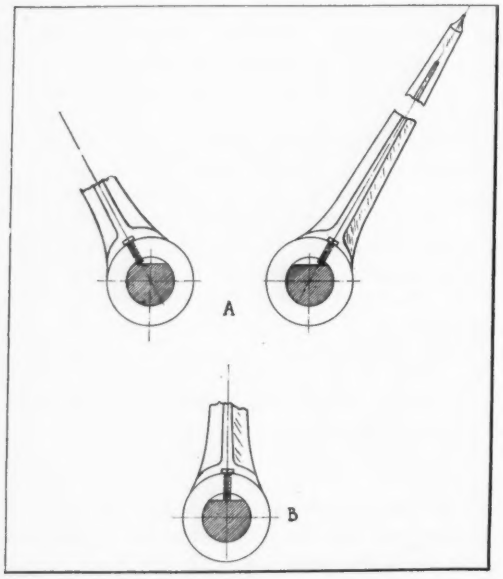


FIG. 1. SHORT SET SCREW ON SYNCHRONOSCOPE POINTER CAUSE FAULTY INDICATION

repair while at the same time attending to his routine duties in the plant.

In order to bestow the proper care upon the equipment under his charge, it is necessary, therefore, that the plant operator, not only have an understanding of the principles involved in the machinery but also of all conditions which might prove detrimental or limit the useful life of the machines.

Of all causes of failure of electrical apparatus, the two chief ones, are excessive heating and moisture. The former, particularly, is a common offender and while in many cases, the effects of heating are not at once noticeable, the life of the machine may be seriously curtailed.

It is perhaps an unfortunate thing from one point of view, that electrical equipment, particularly motors and generators, stand up so well under what in another piece of machinery would be considered a severe overload. If for instance, an electric motor or generator would refuse to function when the overload carried exceeded say 10 or 15 per cent, there would be a great decrease in the number of failures due to excessive heating. Far too much advantage has been taken of the ability of electrical machinery to carry high overloads for short periods of time. Some men do not seem to realize that if a machine is run continuously say at 10 per cent overload, the insulation is gradually being baked to destruction and that sooner or later (mostly sooner) the machine will fail.

Ordinarily, a good motor, generator or transformer will last 25 yr. and then still be in good condition. But if this same machine is operated continuously at an overload of from 10 to 15 per cent, it is not to be wondered at that it burns out say after 8 yr. of operation.

So, in the operation of electrical equipment one of the most important things to be guarded against is the overloading of machines for excessively long periods. Overloads of relatively short duration are not as a rule harmful because the temperature does not increase fast enough to do damage to the insulation.

To protect motors and generators against damage from excessive heating the thermal relay has proved of great value. As was indicated in the preceding paragraph, a motor or generator need not be relieved of its overload

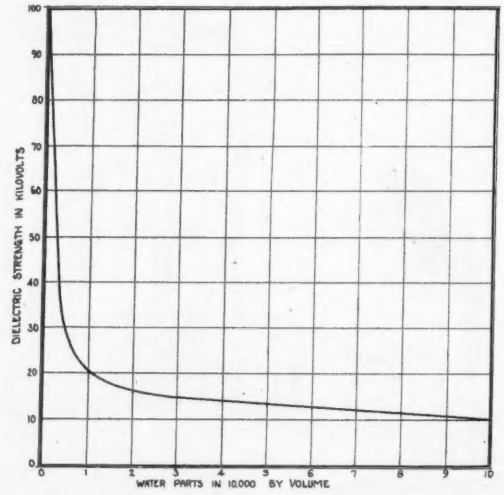


FIG. 2. CURVE SHOWING THE VARIATIONS IN DIELECTRIC STRENGTH OF TRANSFORMER OIL DUE TO MOISTURE CONTENT

until the temperature has reached a value where it will damage the insulation. This is true particularly in the case of the induction motor. It is merely necessary therefore to provide a device which possesses the same thermal characteristics as the machine itself. The thermal relay does this. In some cases, the relay is mounted directly on the motor or generator being protected and is actuated by the heat of the machine itself. When the temperature reaches a predetermined value, the relay acts and the circuit breaker trips out.

It is a curious fact that as the equipment in our power plant becomes larger, we depend more and more upon instruments to inform us of operating conditions and performance. It is therefore necessary to check all instruments at regular intervals in order to be absolutely certain as to the correctness of their indication. A faulty temperature indicator costing not more than twenty-five or fifty dollars can easily be the indirect cause of a burnout costing from a thousand dollars upward.

In synchronoscopes, particularly, instrument errors may result in serious accidents if not discovered. In one instance a consulting engineer was called into a plant to investigate a case where trouble was experienced in the paralleling of generators. The synchronoscope appeared to rotate correctly but when the incoming machine was running slow and was thrown in at synchronism, there was a decided disturbance and "grunting" in the machines. On the other hand, it was noticed that when the incoming machine was running slightly fast and then thrown in there was not the slightest bit of trouble.

Connecting a portable synchronoscope in parallel with the station synchronoscope revealed the fact that the station synchronoscope was over ¼ in. off when running from the slow direction, but was correct when rotating in the fast direction. Removing and dismantling the instrument quickly revealed the cause. The pointer was supposed to be fastened to the shaft by a small setscrew and there was a flat on the shaft to receive the setscrew. The setscrew however was too short to reach the flat and allowed the pointer to turn about ¼ in. before striking the sides as shown in the accompanying illustration. A longer set screw entirely eliminated the difficulties.

While on the subject of electrical instruments a few words of caution may be given in regard to connecting instruments up to circuits of correct voltage and current, particularly when using portable instruments. Make certain that the current in the line to which the instrument is connected will not injure the instrument, or that the method of connecting the instrument will cause no trouble on the lines.

Motor and Generator Troubles

It is not the purpose of this article to discuss in detail the troubles and their remedies encountered in the operation of electric motors and generators. We wish to point out, however, in a general way some of the conditions which are responsible for these troubles. Overheating and moisture has already been referred to. Next in the order of importance comes the lack of proper cleaning, and oiling.

Now, the oiling of an electric motor or generator appears to be a simple procedure, but unless certain precautions are taken trouble will result. In filling the oil cups, care must be taken to avoid flooding of the bearings. If this precaution is not observed, oil may find its way to the commutator if it happens to be a direct current machine, or into the windings. Oil on the commutator will pick up dirt and ground carbon, forming a sticky paste which will result in commutator troubles. Oil working its way into the windings causes them to clog up with dust, reducing the heat radiating qualities and weakens the insulating qualities.

To avoid these troubles, always determine the level of oil in the bearings before adding new, and see to it that the oil rings are working properly. The bearings should be drained about once every 60 days and filled with fresh oil, free from dust and dirt.

To clean the windings occasionally, blow them out with compressed air having a pressure of not more than 50 lb. per sq. in. with a ⅛-in. nozzle to avoid injury to the insulation.

Another factor of importance is the proper inspection of machines and the prompt replacement of worn parts. Grounds, shorts, opens, etc., are often traced to rubbing of the rotor on the field poles caused by a bent shaft or worn bearings. Loose commutators, loosening of bolts, brushes too tight in their holders are only a few of the many things which cause shutdowns.

It is advisable therefore to make a systematic inspection of the machines once a week or at least once a month. At such times the machines should be cleaned with compressed air as described, the brush holders, studs and leads carefully wiped off, oil wells filled, brushes examined and replaced if necessary, air gaps and shaft alinement checked, bolts tightened, commutator examined for pitting, high mica, loose bars, etc.

In the case of new d.c. machines, especial care must be given the commutators. During the first few months

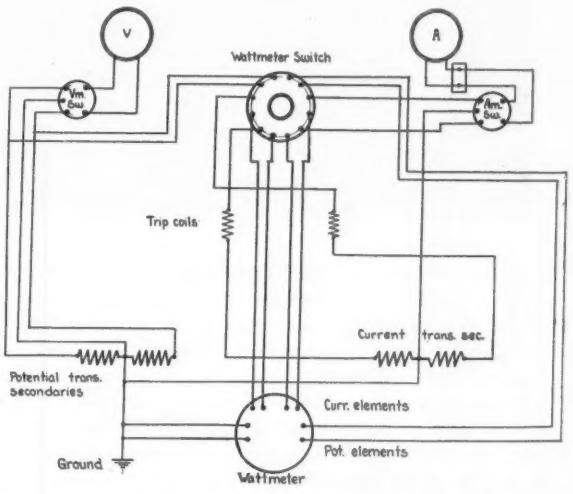


FIG. 3. COMMON METHOD OF CONNECTING SECONDARY ELEMENTS IN SWITCHBOARD PRACTICE

a machine is run under load, the commutator undergoes a process of seasoning. The mica is settling into its permanent position, and the binding material, is working out from points under pressure. During this time the commutator bolts should be tried every two or three weeks while the machine is warm and if found slack, should be taken up tight. In setting up the bolts, a little slack should be taken on each one all the way around, then a little more until all are tight.

As a rule, the color of a good commutator will vary from a light straw to a dark brown or even a blue gray, and will have a high polish. The actual color is of little consequence as long as the bars are polished uniformly from edge to edge.

Ring Fire and Flashing

Ring fire is the designation which has been given to that kind of sparking where rings of fire (electric arcs) embrace the circumference of the commutator, wholly or partially encircling it. This kind of sparking may be divided into two classes: (1) Ordinary ring fire, which is of a reddish tint and may exist on all commutators to a limited extent and, (2) Armature defect ring fire which is of a bluish green color and is more intense than that of the ordinary class.

Ring fire is originated ordinarily by minute arcs which form between adjacent commutator bars. Conducting materials may lodge between the bars, in or on the surface,

and the current passing between the bars through these conducting paths renders these particles incandescent.

To prevent trouble due to dust and dirt on the commutator, it should be washed off with a rag damped with gasoline while the machine is shut down. Care must be taken not to use too much gasoline. Kerosene should never be used, because it lodges in the mica and never dries.

Care of Transformers

What has been said in regard to the overloading of motors and generators applies equally well to transformers. Heating must be watched more carefully in large transformers than in small ones. While it is true that the losses expressed in per cent of the total input are greater in a small transformer than in a large one, the total amount of radiating surface in small transformers as compared with the losses are also much greater. The heat loss in a large transformer may be 40 times as much as in a small unit, yet the total amount of radiating surface in the former may be only four times as much as in the small one. Small transformers therefore do not require any special means of cooling other than that provided by their natural radiating surface. Large transformers do not have sufficient radiating surface to keep them cool so special means such as cooling by air, water or oil are usually provided.

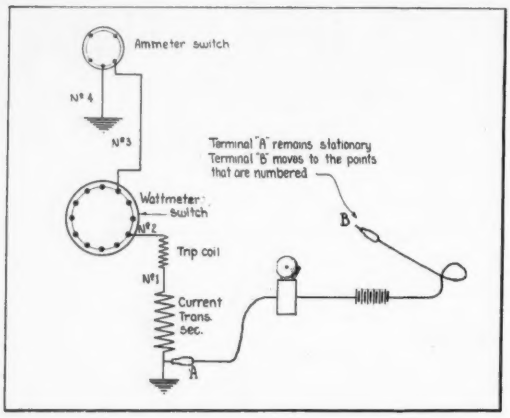


FIG. 4. SIMPLIFIED DIAGRAM OF CIRCUIT SHOWING APPLICATION OF TEST SET

While the mineral oil usually used in transformers is one of the most excellent insulators known, a slight amount of moisture in the oil will destroy its insulating properties to a marked degree. The curve shown in Fig. 2 illustrates this fact clearly. It shows that the water present in oil must not exceed 0.001 per cent in order to obtain a dielectric strength of 40,000 v. In the operation of transformers, therefore, it is extremely important that periodic tests be made of the dielectric strength of the oil.

Switchboard Troubles

In ordinary electrical operation, little trouble is experienced with switchboards or switching apparatus, except when such apparatus is subjected to abnormal stress due to extreme overload or short circuits. If the equipment is kept clean, well oiled, and if the contacts are renewed when necessary, cases of trouble will be rare.

Occasionally, however, especially where changes have been made in the wiring of a switchboard faults will be found to exist. In cases where commutating switches for voltmeters, ammeters, wattmeters, ground detectors, etc., are enclosed in cases exactly alike, there is a possibility of the face plates, having been reversed, and the switches may have been installed in other than their proper places. This is often the case in a new switchboard, just installed.

It is ordinary practice in switchboard work to ground the common connection between the two potential transformers and between the current transformers as shown in Fig. 3. With these connections, it is impossible to make any satisfactory tests with battery and telephone receivers on account of the fact that there is a metallic connection between all wires of potential and current circuits either directly or through the instrument transformer windings. An open circuit or a ground can not be detected since a test buzz will be obtained either forward or backward from any particular point.

To locate trouble in an installation of this type, it is necessary to first open all connections to transformer secondaries and disconnect ground wires at all points.

Let us suppose for instance that the trouble has been with the trip coils, or any of the current circuit devices. Connect one side of the test set (Fig. 4) to one lead from one current transformer secondary (not the lead that went to neutral ground but the one that takes the board circuit).

Now with the other side of the test set. Follow this lead along in successive steps as indicated in Fig. 4 until the buzz fails to result. At each step, take in one more element of the board in the order at which they are arranged. The first step will probably be just through the trip coil in that lead. If this tests O. K. take another step which will include the wattmeter switch. This should give a test buzz with the switch in "off" or any of the three "on" positions. In case no trouble has yet developed, proceed so as to include the ammeter switch. This should also give the test buzz with any position of the switch due to the fact that in any position of current switches the current circuit must be completed either through the instrument when "on" or through the switch when "off." On including the ammeter switch the circuit should be complete, bringing up at the point where the ground wire was disconnected at the beginning of the test.

Failure of the test at any of the successive positions indicates that the trouble must be an open in the switch if in the "off" position as regards that phase, or in the switch or instrument and its leads to the switch if in the "on" position as regards that phase. If the trouble is reached at some particular switch when in the "on" position the investigation must be carried further to ascertain whether the trouble is in the instrument, or leads from the switch to the instrument.

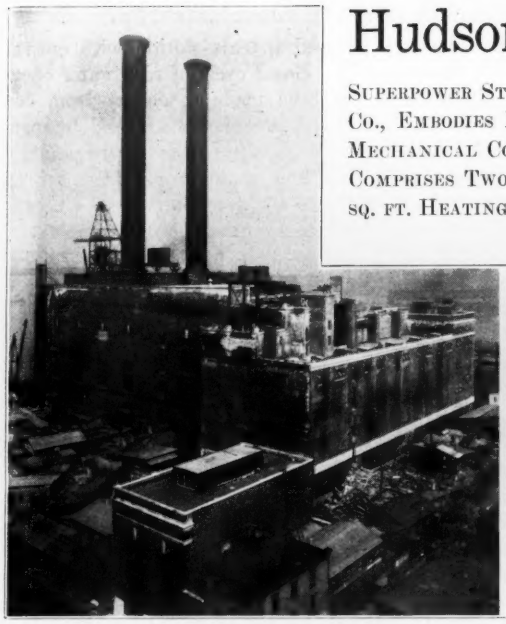
If a shorting of the terminals of the instrument gives the test buzz at the point of trouble, the open is in the instrument; if not, the open is in the switch or in the leads from the switch to the instrument.

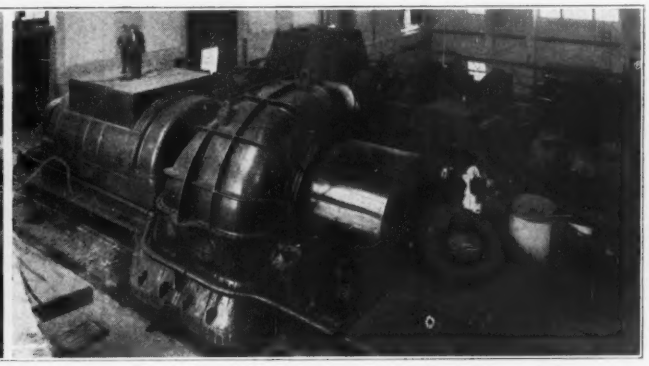
If no test failure is encountered, the trouble must be a short rather than an open and the process should be repeated with the instrument coils disconnected.

While the foregoing does not include all of the various tests to be made in hunting for switchboard trouble, the method of procedure described will suggest other tests. Each switchboard because of differences in wiring and because of different surrounding conditions will require its own method of attack.

Hudson Ave. Plant in Operation

SUPERPOWER STATION DESIGNED BY THE ENGINEERS OF THE BROOKLYN EDISON CO., EMBODIES REFINEMENT IN HEAT BALANCE, ELECTRICAL EQUIPMENT AND MECHANICAL CONTROL, WHICH PLACE IT IN THE FOREFRONT. FIRST SECTION COMPRISES TWO 50,000-KW. TURBINES AND EIGHT BOILERS EACH WITH 19,650 SQ. FT. HEATING SURFACE. CONDENSERS WITH 70,000 SQ. FT. COOLING SURFACE.





BROOKLYN, noted long for the multiplicity of its churches, and more recently for the pertinacity of its statesmen, has come into its own in another field; for the erection by the Brooklyn Edison Co. of a superpower station on the East River, at the foot of Hudson Avenue, has added one more link to the chain of similar plants which furnish an index of present day American efficiency. Anyone visiting this station will appreciate that the engineers of this company, to whom, in collaboration with the firm of Thomas E. Murray, Inc., as consulting engineers, its design is due, have accomplished a work of prime significance.

COAL AND WATER SUPPLY DETERMINED LOCATION

Location of the site of this plant was determined primarily by the necessity of making adequate provision for supply of coal and circulating water. Since the territory supplied with light and power by the company, Brooklyn Borough, which has the same limits as Kings County, contains no central point at which these requisites are available, it was necessary to choose a site relatively far from the center of the district. The place chosen adjoins the Brooklyn Navy Yard on the east and extends south from the East River to a point south of Marshall Street. This street is crossed at the second story level by cable bridges between the main turbine room on the north side and the switch house on the south. Beyond the turbine room lies the boiler house, with the coal towers next the river. The Gold Street Station of the company is also located on the East River, a block west of Hudson Avenue.

Since the territory served by the company is large, with a population of over two million, the average distance for transmission to the various substations from the Hudson Avenue Station is some 5 mi. Careful study was therefore devoted to the problem of transmission voltage, to determine whether 13,800 v. should be retained. The problem was complicated by the fact that subsurface congestion in the neighborhood rendered 13,800 v. transmission undesirable unless considerable private property were acquired. It was found that transmission of 27,600 v. should be more economical for an average distance exceeding 3 mi.; that the purchase of four additional private lots would add one street to the two available for duct lines, so that by placing two ducts in each street a total of six could be accommodated; that doubling the voltage would permit use of 2 to 1 auto transformers with 13,800-v. generators; and that the old 22,000-v. cable could be used at the higher voltage, with new petrolatum filled splices equipped with reservoirs. Hence the decision to adopt 27,600 v. for transmission was made.

Ground was broken during August, 1922, and it was then believed that operation would be commenced toward the end of 1923; but owing to delays in the foundation work operation was not started until May 1, 1924.

The typical foundation consists of re-inforced concrete mat resting on piles, for the boiler and turbine rooms, and a 6-ft. mat for the switch house. Some details of quantities on this work were given on p. 177 of our issue of February 1, 1923. On the river side, a sheet piling wall separates the boiler room mat from a bank of rip-rap backed up with sand and stone and pinned down with bearing and batter piles. Above this is the concrete dock for coal tower support.

DIFFICULTIES ENCOUNTERED IN TUNNEL CONSTRUCTION

Eleven cofferdams were constructed for the circulating water tunnels, and this feature of the work proved the most difficult, owing to local soil conditions. Pumping out of cofferdams led to various troubles due to movement of the bottom, and it was necessary to evolve methods for pouring a sealing course of tremie concrete under the reenforced concrete of the tunnel bottoms, and also for driving piles below water. Using a hammer devised by the Frederick Snare Corporation in connection with the McTierney-Terry Drill Company, piles were cut to approximate length, put in place under water, and driven to allowable grade.

Of the ultimate capacity of 400,000 kw. as planned, divided into four groups of two 50,000-kw. units, the first group has been put in operation and one unit of the sec-

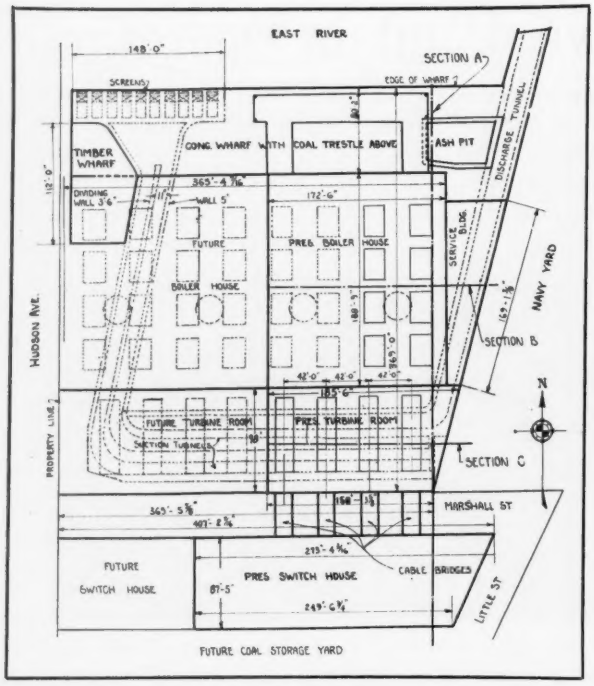


FIG. 1. HUDSON AVE. STATION IS LAID OUT FOR FOUR SECTIONS OF TWO 50,000 KW. UNITS

ond group has been ordered. It is expected that a continuous program will carry the entire work to completion to meet the growing demands of the community.

The Hudson Avenue Station will operate at 60 cycle frequency, which is also employed at the 66th Street Station of the Brooklyn Edison Co. The Gold Street Station, however, generates at 25 cycles, and to balance the system a 35,000-kv.a. frequency changer is installed in a separate building south of the switch house. This unit has been in service since last November.

Heat Balance and Outstanding Features

Heat balance is secured in this station with entirely automatic regulation by a closed cycle of feed water operations. No attempt has been made to depart from conservative practice as regards steam pressure and temperature of superheat but bleeding of steam from two points in each main unit is done and space is provided for the installation of air preheaters or economizers if either of these steps appears justified by future developments.

Final decision on the scheme for obtaining heat balance was made after consideration of four methods of feed water heating which are in common use:

(1) From hot wells of main condensers to open heaters to boilers.
(2) From hot wells to open heaters through economizers to boilers.
(3) From hot wells to closed heaters supplied by bled steam from main turbine; thence through economizers to boilers.
(4) From hot wells to low pressure and high pressure heaters, both supplied with steam from main turbines, thence to boilers.

Since the use of steam driven auxiliaries was not considered advisable, the first two of these were eliminated, and a study was made to decide the question of economizers. The result of this inquiry has been stated at the close of the preceding paragraph.

In the system adopted, feed water for one group is delivered from the condenser hotwells of the two main units by hotwell pumps through air ejectors and a common header to the condenser of the 4500-kw. house turbine, where it acts as circulating water. Make-up water is derived from a surge tank floating on the discharge side of this condenser. Here also enter the hotwell discharge from the house turbine condenser, the overflow from a 45,000-gal. storage tank supplied by the surge tank overflow and the discharge from eductor condenser on high pressure packing of the General Electric main turbine, and the condensate from closed heaters. From this point the

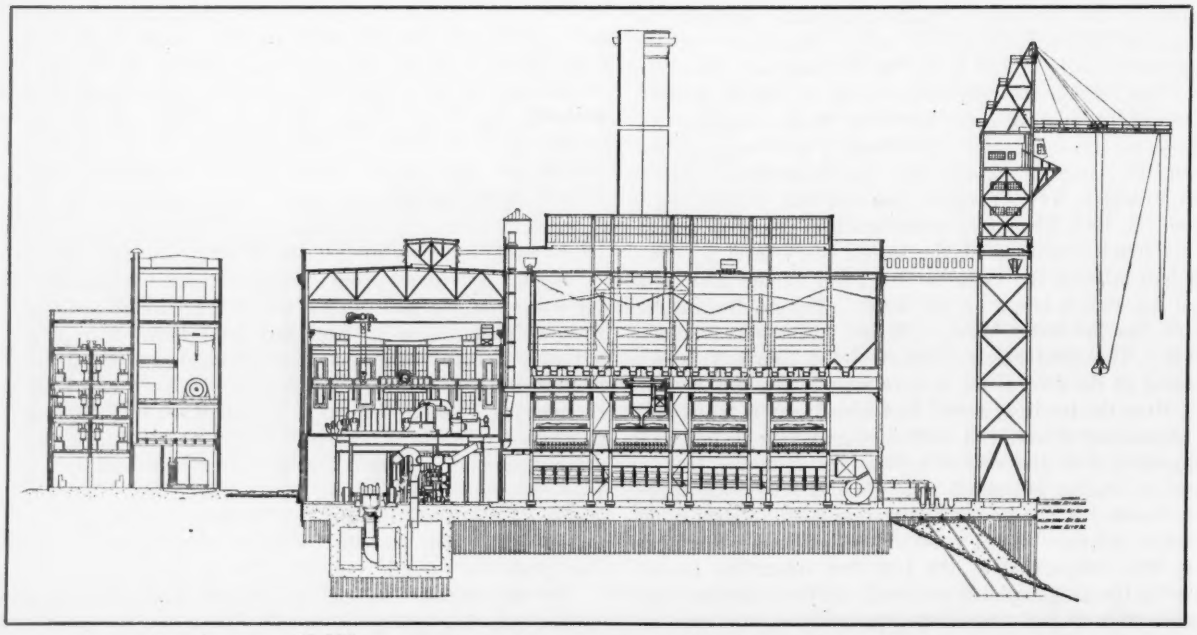
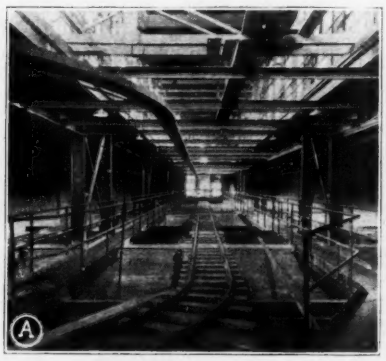
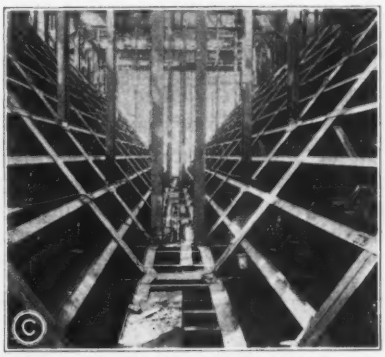


FIG. 2. TWO 50,000 KW. UNITS HAVE BEEN INSTALLED AND ANOTHER UNIT IS IN ORDER

Fig. 3. Interesting Details of the Hudson Ave. Station





A. Coal is handled by coal towers, which are used to unload the boats and it is then conveyed to the bunkers by electrically operated cars.

B. The turbines in the station are the largest single cylinder machines which have ever been built. This view shows a turbine rotor under construction. The rotor was completely assembled in the vertical position before being placed in the turbine.

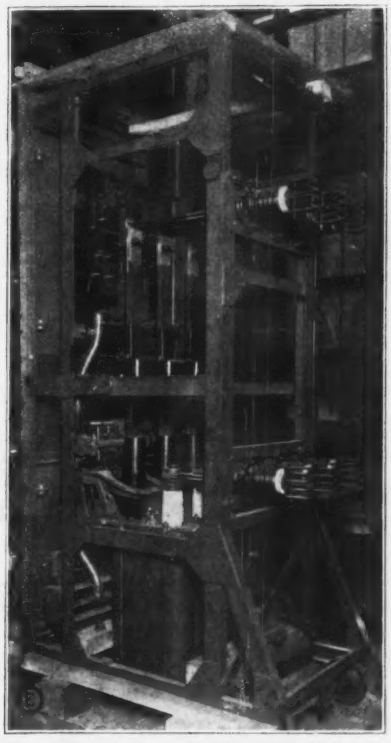
C. Since the bunker capacity is larger than ordinarily found, due to the lack of outside storage space, the steel work is of massive proportions.

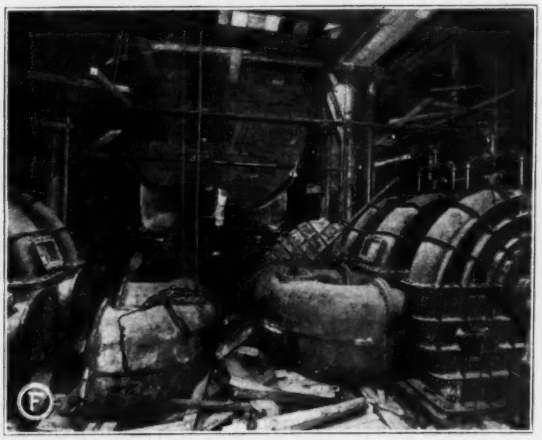
D. Truck type switchboards are extensively used in the station. This view shows the construction of the compartments and the plug type receptacles which are used on the busses.

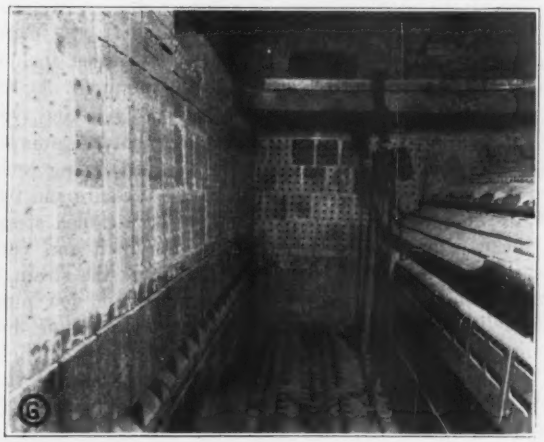
E. One of the truck type switch panels showing the spring contacts which are used.

F. Circulating pumps which supply the cooling water for the 70,000-sq. ft. condensers.

G. Part of the stokers are equipped with single roll clinker grinders and part with the double roll type. Air is introduced through the side walls and the rear wall.







feed water is drawn through the boiler feed pumps and forced through low and high pressure heaters, one pair of which is supplied with steam from each of the main turbines. It then goes to the boilers and superheaters, and as steam at 265 lb. gage pressure and 200 deg. F. superheat at the throttle, through the main turbines and condensers to the beginning of the cycle.

Major Equipment for One Group

As at present constituted, the group involved in the performance of this cycle consists of two main turbines—one General Electric and one Westinghouse—of 50,000 kw. each, driving generators of 62,500 kv.a. at 80 per cent power factor; one 4500-kw. Westinghouse turbine, with 6000 kv.a. generator at 75 per cent power factor; two 70,000 sq. ft. Westinghouse two-pass surface condensers of radial flow type, and one 4000-sq. ft., four-pass Westinghouse surface condenser, with their auxiliaries, including for each main unit two circulating pumps of 50,000 g. p. m. each, one hydraulic air pump of Le Blanc type and one air ejector unit, and two 2-stage hotwell pumps; three centrifugal boiler feed pumps of 1500 g.p.m. each, one of which is turbine driven; two high pressure and two low pressure closed feed water heaters taking bled steam in the case of the G. E. unit from the 10th and 16th stages, while with the Westinghouse turbine the steam is drawn from the main connecting the high and low pressure cylinders and from the point where the double flow element of the low pressure cylinder begins; and eight B. & W. crossdrum boilers of 19,650 sq. ft. heating surface, with B. & W. single loop superheaters of 2508 sq. ft. superheating surface.

Furnaces have a height of 21 ft. 10 in. from the floor to the bottom of the front header, and a width of 24 ft. 8 in., with furnace volume of about 7500 cu. ft. Boilers are 42 tubes wide and 20 high, the superheater being set above the lower bank of six tubes. Drums are of 1 in. steel, 54 in. in diam. and 30 ft. 6 in. long. There is a 10-in. steam outlet near each end, and provision for the six safety valves.

Six of the present boilers are equipped with 14-retort Westinghouse underfeed stokers, and double roll clinker grinders, the right and left hand sides of which are driven separately from Westinghouse direct current motors of 300 1200-r.p.m. Stoker drive is accomplished by direct current variable speed motors with silent chain drive. Both the stoker and clinker grinder driving motors are located on the boiler room floor, giving easy access for operation or maintenance work.

Two boilers of the present installation and four more which have been ordered are equipped with the New Frederick type stoker, 14-retort, 31 tuyeres long. A secondary ram action on these machines pushes forward a series of tuyeres and increases the effectiveness of combustion. The projected grate area of these stokers is 380 sq. ft.; that of the Westinghouse stokers, about 356 sq. ft.

Electric Drive for Auxiliaries

With the exception of one boiler feed pump already mentioned, all auxiliaries are driven by electricity. Wherever possible, a. c. motors are used; but in case of certain auxiliaries requiring variable speed, such as the stoker shafts clinker grinders, 250 v. d. c. with Ward-Leonard control is employed. For this purpose, there is a 4-unit M.-G. set consisting of 1000 kw. and 300 kw., 250 v. d. c. generators, a 100-kw. d. c. exciter, and a 1725-hp., 2300-v., 3-phase, 60-cycle synchronous motor.

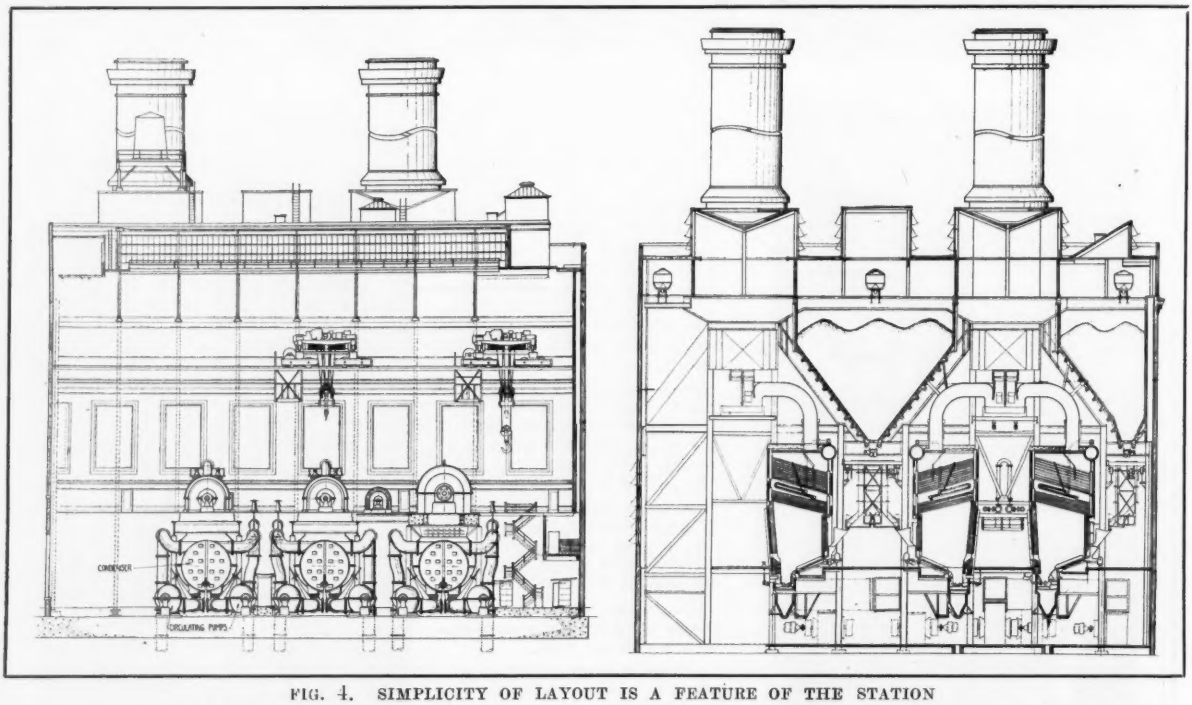


FIG. 4. SIMPLICITY OF LAYOUT IS A FEATURE OF THE STATION

From the sectional view of the turbine room it will be noted that the condensers are served by two circulating pumps. Since these condensers are also built with divided water boxes, considerable flexibility of operation is possible. This view of the station is marked section A on the plan view of Fig. 1. The view of the boiler room is section B of the plan view. One feature of the boiler room is the large bunker space provided, which is necessary on account of the lack of outside space.

All a. c. drives below 50 hp. are by induction motor with starting compensators.

For reliability of power supply to the 2300-v. bus serving the main station auxiliaries, great care has been taken to provide three sources of power, so that the worst that can happen with the loss of one source is temporarily to lose half the essential auxiliaries, as they are divided into two groups and draw from independent sources. All auxiliary motors over 50 hp. are run from the 2300-v. bus. Dead front truck type switches are employed. The three sources of power are (1) the house turbine, with 6000-kv.a., 3-phase, 60-cycle generator (2) a 6000-kv.a., 25-cycle, 60-cycle frequency changer supplied from the 25-cycle station; and (3) a 6000-kv.a. house transformer, fed from the main bus.

Other mechanical features which must be included to give a fair conception of this station are: a coal handling system as automatic as could be devised with due regard to safety and reliability, with two traveling towers of 250 T. per hr. capacity, automatic motor cars for delivery from towers to bunkers, automatic weighing on the tracks and at lorries, unusually large bunker capacity to provide for lack of outdoor storage, and delivery from bunkers to stoker hoppers by means of traveling lorries; stacks of unusual height, obviating the necessity for induced draft equipment; ash disposal from clinker grinders through sluiceways to a submerged storage pit, whence the refuse is excavated by a crane with 5-T. bucket; and a boiler control room in the boiler house, where supervision of boiler operation is centralized.

On the electrical end, the following items of unusual interest may be noted: direct connection between 13,800-v. generators and auto transformers, stepping up to 27,600 v. for transmission; arrangement of main circuit breakers with vertical phase isolation, the three phases being on successive floors, with the operating mechanism on the floor above the top phase; construction of these breakers with all auxiliary apparatus, disconnects, current transformers, and the like, in the switch itself, eliminating compartment construction and facilitating inspection or removal for maintenance work; provision of individual steel cubicles and housings for the generator and feeder control benchboards and panels, with the housings extending through the floor and terminal blocks located in the cable room below; and provision of exceptional facilities for testing both feeders and electrical instruments.

In a subsequent issue we shall deal more specifically with some of the items to which reference has been made, particularly the matter of heat balance.

Motor Standardization of the Electric Power Club

SOME YEARS ago the Electric Power Club, which is an association of electrical manufacturers, began a program of standardization for electrical motors with a view toward reducing manufacturing costs and simplifying the application problems of the user. Certain limitations for belt and gear drives and sizes of shafts, shaft extensions, keys and pulleys are a few of the standards which have been developed during the course of this work.

In connection with belt and gear drives, it is recommended that belt drive be limited as follows: 1800 or 1700 r.p.m. motors should be limited to a maximum of 40 hp.; 1500 or 1400 r.p.m. to 50 hp.; 1200 or 1100 r.p.m to 75 hp. and 900 or 850 r.p.m. to 125 hp. These limits are based on the use of standard pulleys as shown in the accompanying table. The limitations are less than those given when motors are belted to slow speed drives such as counter shafts.

When motors are geared and steel pinions are used, the following limitations are suggested: The use of 1800 or 1700 r.p.m. motors should be limited to a maximum of 5 hp.; 1500 or 1440 r.p.m. to 10 hp.; 1200 or 1150 r.p.m. to 25 hp.; 900 or 850 r.p.m. to 50 hp. and 750 or 720 r.p.m. to 75 hp.

1. Standard dimensions for paper pulleys applicable to general purpose motors having continuous time ratings for the load and speed ratings indicated shall be:

H. P. at 1750-1800 R. P. M.	H. P. at 1150-1200 R. P. M.	H. P. at 850-900 R. P. M.	Pulley Diameter Inches	Pulley Width Inches	Belt Width Inches	Pulley Bore Inches
1	¾		3	2½	2	¾
1½	1		4	3½	3	⅞
2	1½		4	3½	3	1
3	2		4	3½	3	1
5	3		5	4½	4	1⅛
7½	5	3	5	4½	4	1⅛
10	7½	5	6	5½	5	1⅜
15	10	7½	7	6¼	6	1⅜
20	15	10	8	6¾	6	1⅜
25			9	7¾	7	1⅜
30	20	15	9	7¾	7	1⅜
40	25—30	20—25	10	7¾	7	2⅛
	40	30	11	11	10	2⅛
	50		12	12	11	2⅛
	60	40	12	12	11	2⅛
	75	50	13	13	12	2⅛
		60	13	13	12	2⅛
	100	75	15	15	14	3⅛

1. Standard shaft extensions for constant speed general purpose motors shall be:

H. P. at 1750-1800 R. P. M.	H. P. at 1150-1200 R. P. M.	H. P. at 850-900 R. P. M.	Shaft Extension Diameter Inches	Key Width Inches	Key Thickness Inches
1	¾		¾	3/16	3/16
1½	1		⅞	3/16	3/16
2	1½		1	¼	¼
3	2		1	¼	¼
5	3		1⅛	¼	¼
7½	5	3	1¼	¼	¼
10	7½	5	1⅜	⅜	⅜
15	10	7½	1⅜	⅜	⅜
20	15	10	1⅜	⅜	⅜
25	..	..	1⅜	⅜	⅜
30	20	15	1⅜	⅜	⅜
40	25—30	20—25	2⅛	⅜	⅜
50	..	..	2⅛	⅜	⅜
	40	30	2⅜	⅜	⅜
	50	..	2⅜	¾	⅜
	60	40	2⅜	¾	⅜
	75	50—60	2⅞	¾	⅜
	100	75	3⅛	¾	⅜

PULLEY DIMENSIONS, BELT WIDTHS AND SHAFT EXTENSION STANDARDS

Outboard bearings should be specified for general purpose motors with geared drive in frame sizes 75 hp. 850 to 900 r.p.m. and larger.

In the accompanying table, the standards for pulley sizes, belt widths, shaft extensions and keyways are shown. The length of the shaft extension is not given in the tabulation since it is three times the diameter of the shaft extension. All of these recommendations and standards apply to both direct and alternating current motors.

TO RESHARPEN old files, wash the files in warm potash water to remove the grease and dirt, then wash in warm water and dry by heat. Put 1½ pt. warm water in a wooden vessel, put in the files, add 3 oz. blue vitriol finely powdered, 3 oz. borax. Mix well and turn the files so that everyone may come in contact with the mixture. Add 10½ oz. sulphuric acid and ½ oz. cider vinegar. Remove the files after a short time, dry, rub with olive oil, wrap in porous paper. Coarse files should be kept in the mixture for a longer time than fine ones.

THE INQUIRING ENGINEER

The Inquiry

Automatic combustion control is becoming more and more of a necessity in the better class of boiler plants today. No one denies that a good system properly applied can effect worthwhile savings in the operation of a plant. The question is what general type of system will show the best results? What parts of the combustion system should be controlled from what source? Should the stoker drive, the forced or the induced draft fan or the uptake damper be controlled from the steam pressure, the steam flow, the over-fire draft, differential draft through the setting or percentage of CO_2?

Replies

O. S. Carter,

United Gas Improvement Co., Philadelphia, Pa.

We favor an arrangement whereby the furnace controller actuated by draft intensity operates the forced draft fan or the damper controlling the supply of forced draft.

Individual dampers or induced draft fans are operated directly by the steam pressure regulators (or steam demand) and the rate of fuel feed can be controlled by the same regulator.

The system would operate as follows: A demand for steam causes a slight steam pressure drop, the individual dampers or induced draft fans will be operated by the damper regulators causing an increase in furnace induction. The rate of the fuel feed will be increased a proportional amount.

The increased furnace draft will cause the furnace controller, which has been set at a pre-determined pressure, to increase the forced draft. The furnace having high resistance fuel bed will have a high under grate pressure and the furnace with a thin fuel bed will have a low pressure.

As the over fire draft remains nearly constant each furnace will receive an equal increase in the amount of air supplied, which will again bring the steam pressure back to normal. As the pressure increases the stack dampers will again close slightly, causing a small decrease in over fire draft, which will, by means of the furnace controller, cause a reduction of the forced draft. If the steam pressure regulators are of the proper compensating type a constant steam pressure can be maintained.

Leo F. Grandmontagne, Chief Engineer,

Republic Rubber Co., Youngstown, Ohio.

One of the principal factors entering into the choice of a combustion control system is the type of stoker employed. The type of stoker depends a good deal on the kind of fuel to be burned. Ordinarily chain grates or over-feed stokers are best adapted to highly volatile coals that are used to best advantage with natural draft. Coals running high in ash are perhaps best burned in the underfeed type stoker. The fuel bed is usually thinner where natural draft is used as the blowers can take care of a heavier fuel bed together with the high temperature and small excess of air which with proper damper control makes possible the highest CO_2 and total combustion efficiency. In a small plant the regulation is sometimes left to the boiler operator and if he is continuously alert he can possibly regulate the draft and fire to suit the conditions.

In a large plant, however, automatic regulation is best and if kept in proper working order by a man who understands the principles of combustion it will save fuel.

Now the question comes, what is the best method of regulation? This is not the same in all plants. Often, the human factor in the attention of regulation devices is not taken into account, with the result that one plan shows the best results in one plant and another plan, the best results in another.

My own opinion is that the best results are obtained as follows: With under-feed stokers the blowers should be regulated by the steam pressure and the stack damper should be regulated by the over-fire draft to be open just enough to take the gases away from the fire. A zero draft or atmospheric pressure over the fire permits leveling a fire bed without having cold air rushing in. Bare spots in a fire are one of the greatest losses in combustion efficiency.

In case the stack is equipped with an induced draft fan, the regulator can be connected directly to the fan. Where there is more than one boiler on a fan each damper should have its own regulator. I have seen the stoker speed and the fuel thickness, automatically controlled and have always found that this was too sluggish, I think the stoker speed and fuel thickness are best controlled manually by matching the steam flow meter or being notified by a signal from the switchboard or a totalizing wattmeter in the boiler room. Sometimes the steam pressure drops too far before the fuel bed is built up and the automatic damper and blower will usually hold it down when the load suddenly falls off. If the stoker speed could be automatically controlled by the steam flow, this could be bettered, but I have never seen such an arrangement. With chain or over-feed stoker and natural or induced draft I

believe the best plan is to have the damper regulated by the steam pressure and the stoker speed manually. With this type stoker and the usual ignition arch, the stoker responds more readily to regulation than does the under feed.

W. H. KAPITZKE, New Haven, Conn.

It has been my experience that the simplest and most satisfactory means of controlling forced draft blowers is from the steam pressure. When a sudden demand for steam occurs there is a tendency toward a drop in steam pressure which automatically increases the blower speed and, therefore, the wind box pressure. This pressure in the windbox is then utilized indirectly for the control of the draft and fuel feed.

For a given fuel bed resistance the increased wind box pressure causes an additional quantity of air to enter the furnace through the fuel bed. This means a greater volume of gases to be exhausted and a less efficient process of combustion unless additional fuel is introduced to compensate for increased air supply.

If, then, the individual boiler damper is controlled by the draft over fire the damper position is changed the proper amount to care for the increased gas volume. With the apparatus controlling the damper also connected to the stoker drive control the regulation is found to be quite good.

It should be borne in mind, however, that any automatic stoker speed control is good only for a coal of constant quality and that the most satisfactory regulation, when such is not the case, is hand control by an intelligent operator.

S. C. MARTIN, Schenectady, N. Y.

In regard to the use of automatic regulation in connection with pulverized coal fuel, it is my opinion that at least three separate controls would be necessary.

First: Control of the quantity of fuel and air mixture admitted to the furnace. This quantity depends upon the steam pressure variation.

Second: Control of the ratio of fuel and air in the mixture.

Third: Control of the uptake damper or the draft; the draft maintained being dependent upon the quantity of fuel that is being fed to the furnace.

The first control may be operated then by the steam pressure, the second by means of the CO_2 content of the furnace gases and the third either by the steam pressure or by the difference in draft inside and outside of the furnace.

When changing the amount of the mixture admitted to the furnace, it might be necessary to vary the ratio of the fuel and air. Regulation would be simplified if the total amount of air admitted to the furnace were supplied with the fuel and if the fuel were uniformly fine and dry.

I feel that it will not be possible to apply automatic regulation to the various types of pulverized fuel installations with uniform success, until furnace construction, degree of pulverization and the method of burning have become more standardized.

Notes on Centrifugal Pump Specifications

SERVICE REQUIREMENTS ARE PRINCIPAL DATA NEEDED BY DESIGNER; SERVICE RECORDS SHOW DEPENDABILITY OF CENTRIFUGAL PUMPS. BY JOHN D. MORGAN

ALTHOUGH the average engineer, architect and user reached the conclusion long ago that centrifugal pumping equipment had reached a stage in which no striking improvements could be looked for, it is an established fact that while centrifugal pumping equipment is approaching maturity, yet there has been many small improvements made which justify considerable study. For certain purposes the centrifugal pump has practically displaced reciprocating pumps and with the ever increasing congestion of homes, apartments, office buildings and factories, it is well for us to devote considerable time and study to the design, construction and operation of centrifugal pumping equipment.

There are several reasons why centrifugal pumping equipment has displaced the reciprocating unit. To recall them to your attention is a matter of few words: lower cost for capital charges, power, superintendence, repairs, labor, supplies, smaller foundation, less weight, less building room and more quiet in operation.

Let us now take up the various design features and calculations in so far as they are an aid to the proper specification of medium size centrifugal pumping equipment. In order that the pump may be designed to function properly for the work in question, it is first of all necessary to have certain fundamental data such as that contained in the data sheet given below:

CENTRIFUGAL PUMP DATA SHEET

1. Capacity g.p.m.....
2. Discharge head, including friction.....
3. Suction lift.....or head.....
4. Diameter of discharge pipe.....
5. Diameter of suction pipe.....
6. Possible variation of discharge head.....
7. Possible variation of suction head or lift.....
8. Nature of liquid to be pumped.....
9. Temperature of liquid.....
10. Specific gravity of liquid.....
11. Size and character of solid matter contained in liquid .....
12. Is service continuous?.....
13. Nature of motive power.....
14. Special conditions .....

One of the most difficult tasks of a designer is trying to design a pump to meet the specifications as drawn up by some engineer or architect, who deems himself eminently fitted to designate the head per stage and various other design features a pump should have. Such items as these, should be left to the discretion of the manufacturer. In the absence of specific instructions the designer must follow sound engineering practices, for a centrifugal pump if it is to do the work, must have a sturdy construction combined with high efficiency. To obtain a sturdy con-

struction is more a matter of strength of materials and this phase will be taken up later, but the principal task so far as the designer is concerned, is that of producing a pump of high efficiency. This is accomplished by the following:

1. The proper determination of the head per stage, or, in brief, the diameter of the impeller. The diameter of the impeller for a medium size pump should not be more than 12-in. in diameter if an efficient pump is to be produced. If a greater head is desired than can be obtained with a 12-in. wheel at the specific speed, it will be

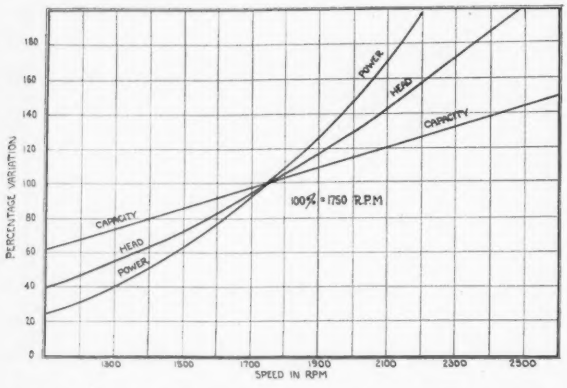


FIG. 1. APPROXIMATE PERCENTAGE VARIATION CURVES

found that a higher efficiency will be obtained if the speed is increased.

2. The width of the impeller is a matter that can readily be determined from the amount of water to be pumped and the other constants used by the designer. A word of caution, however, might properly be injected here, and that is that there is ample evidence that the width of the impeller and the diameter of the impeller should bear some definite relation, if high efficiency is to be obtained.

3. Mechanical losses have, as a rule, given the designer the most trouble. These losses can be divided into the following: Bearing losses, packing friction losses, disc friction losses, waste water losses and wearing ring losses.

Bearing losses are not of great importance if proper care is taken in so far as actual power is concerned; there is but a small amount of difference between the power consumption of the bronze ring oiled bearings, and either the ball bearing, or the rubber bearing. Other conditions than those of power savings, however, enter into the problem and there is a general tendency among the foremost designers, to discontinue the use of the bronze babbit ring oiled bearing and to use either the ball bearing or the rubber bearing.

Packing friction losses are a large variable figure. The tendency has always been for excessive packing friction. If, however, the stuffing boxes are properly packed and the water sealing and packing lubrication ring is in position, this loss is not so great as one would presume.

Disk friction losses are perhaps the most important and strangely one of the losses about which there is a great lack of authoritative data. In general it can be stated that disk friction losses are affected by the following: Viscosity, diameter and width of impeller, angle of the impeller blades in reference to the periphery tangent, width of the waste water chambers, and speed of the impeller as well as the finish of the casing internally, and the outside and inside of the impeller. A brief rule for low disk friction losses is, namely, keep the diameter of the wheel small, all surfaces in contact with the water smooth and uniformly small area waste water chambers.

Waste water losses can be kept at a minimum by properly designed, compact, close wearing rings. Wearing ring losses can be greatly overcome by the substitution of the rubber wearing rings which will reduce, if designed properly, the waste water losses as well as the friction in the wearing rings themselves.

There is still one other point to worry the designer, and that is the multi-stage pump; it is necessary, if high efficiency is to be obtained, to calculate the correct size of a balancing friction to correct the unbalanced pressure created on the impeller. This is only a simple matter of computing the area on which the pressure acts and then computing the correct area of the balancing friction to neutralize this unbalanced pressure.

It must always be borne in mind that at best, the proper calculation of an efficient centrifugal pump is a complicated problem; this can be illustrated by comparison of the speed capacity of a reciprocating pump versus the centrifugal pump; the reciprocating speed capacity curve

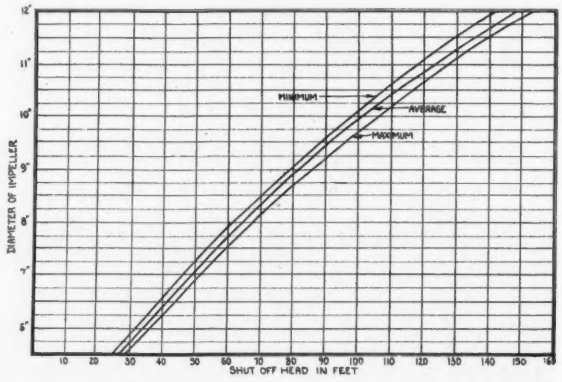


FIG. 2. RELATION BETWEEN THE DIAMETER OF THE IMPELLER AND THE SHUT OFF HEAD FOR A MODERN CENTRIFUGAL PUMP RUNNING AT 1750 R.P.M.

is a straight line, but that of the centrifugal pump is a parabola as is also the head speed curve and the head capacity. There are, however, three approximate rules about the centrifugal pump in relation to its speed, head and capacity and power which, briefly expressed, are as follows: 1. The capacity varies directly with the speed. 2. The head varies as the square of the speed. 3. The power varies as the cube of the speed.

For a constant speed and head, the capacity varies directly as the width of the impeller opening. The shutoff heads produced by various diameters of impellers when operated at a speed of 1750 r.p.m. is shown in Fig. 2.

It might not be amiss at this point to call your attention to the importance of giving the pump manufacturer the true head conditions. This is a simple matter and one need only use the comparative simple formula given below to obtain it. (NOTE:—This formula is based on new and clean pipe of uniform area and free from obstruction.)

Actual or real head equals the static head plus friction head plus suction head. If there is a positive pressure

existing on the suction, such as the city water pressure, this formula then becomes:

Actual head equals the static head plus friction head minus suction pressure. In determining the friction head, the following formula developed by Wm. Cox is fairly accurate.

$$H = L\,(4V^2 + 5V - 2) \div 1200\,d$$

in which

H friction head in feet
V velocity in feet per second
L length of pipe in feet
d diameter of pipe in inches.

One must, however, take into account the loss of head due to friction in the various fittings; this can be calculated from the following formula: $H = C\,\frac{V^2}{29}$ in which C has the following values:

Angles 45 deg.	C	1.82
Angles 90 deg.	C	.98
Valves Gate	C	.182
Valves Globe	C	1.91
Valves Angle	C	2.94

Specifications and Construction

In the main, centrifugal pumps can be classified under four heading names.

1. Single stage vertically split side suction.
2. Single stage horizontally split, double suction.
3. Multi-stage horizontally split.
4. Vertical or sump pump, single or multi-stage.

In this article, there is little need for discussing the first group as these are in the main, a cheap class of pumps put out by manufacturers on account of the purchaser's failure to recognize that a good pump is the cheapest in the long run.

One of the greatest faults of the specification writers of pumping equipment has in part been their great desire to impress the pump manufacturer of their vast store of knowledge. To do this, some of them have devoted page upon page to the specifications of the driving unit. It is my belief that such specifications as those published for motors by the A. I. E. E. were written for the benefit of the designing engineers for motors and therefore, with the large number of reputable motor manufacturers now engaged in the manufacture of motors, all that the average motor specifications need consist of is as following:

The driving unit shall consist of..... or.....motor .....h. p.....volts .....amperes .....phase .....cycle and.....r.p.m.....bearings—ball bearings or bronze ring lubricated and of.....deg. rating.

Installation of Centrifugal Pumps

The foundation of the centrifugal pump is of prime importance. The proper method of installing the foundation is as follows: A good solid foundation of stone, brick or concrete, should be built up with the foundation bolts set in pipe to allow for a slight adjustment. The floor should be left all around the foundation and this strip should be filled with sand. The top of the foundation should be levelled up with the level and a fine finish obtained by the use of neat cement. Upon this foundation should be placed a cork pad about 1 in. thick, the pump bedplate should then be mounted on the pad, in a level position and the foundation bolts should then be drawn down. Care must be taken when so doing, not to spring the bedplate. If this has been done properly, you should be able to turn the pump readily by hand. This method may seem like an expensive method for a foundation, but it will greatly reduce noisy operations and at the same time, insure greater length of life for the equipment.

When connecting up the piping to the pump, it seems to be the great delight of some mechanics when they find that the pipe flange and the piping flange does not meet, to put some bolts in and draw them together, thus springing the pump out of line, and putting on it strains, such

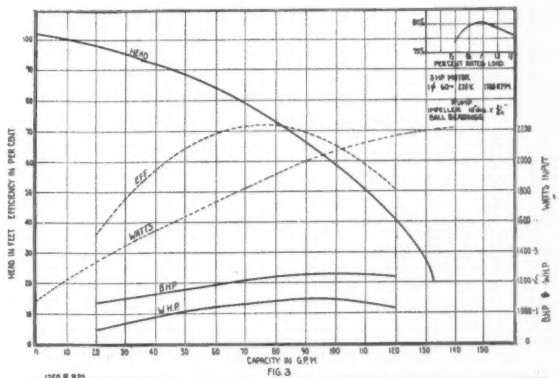


FIG. 3

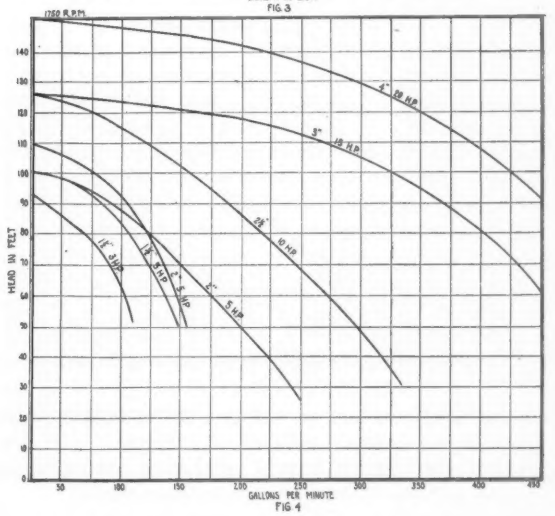


FIG 4

FIG. 3. CHARACTERISTIC CURVES OF A 1½-IN. DOUBLE SUCTION, HORIZONTALLY SPLIT, CENTRIFUGAL PUMP

FIG. 4. HEAD CAPACITY CURVES OF DOUBLE SUCTION PUMPS RUNNING AT 1750 R.P.M.

as it was never designed to stand. To overcome this, the most successful manner is to specify that the pump suction and discharge must be provided with a three foot section of high pressure hose. This will also accomplish the eliminating of some objectionable noises.

For the suction pipe use at least one size larger than the suction size of the pump, and provide it with a foot valve if a suction lift is needed. Great care should be taken to keep our air traps, high spots, install a good strainer, leave out needless tees, elbows, etc. and if you desire to have the pump pump water, keep it air-tight.

On the discharge pipe should be placed a check valve and a gate valve, no reliable pump manufacturer will recognize any claim for broken casings due to water ham-

mer, unless there has been installed a check valve. Whenever possible, have the size of the discharge pipe larger than the discharge pump size, and the discharge pipe should never be less than the pump discharge.

Drain piping should be connected up to the drip pockets in the bearing housing, to take care of the drip from the stuffing boxes, for contrary to the general belief,

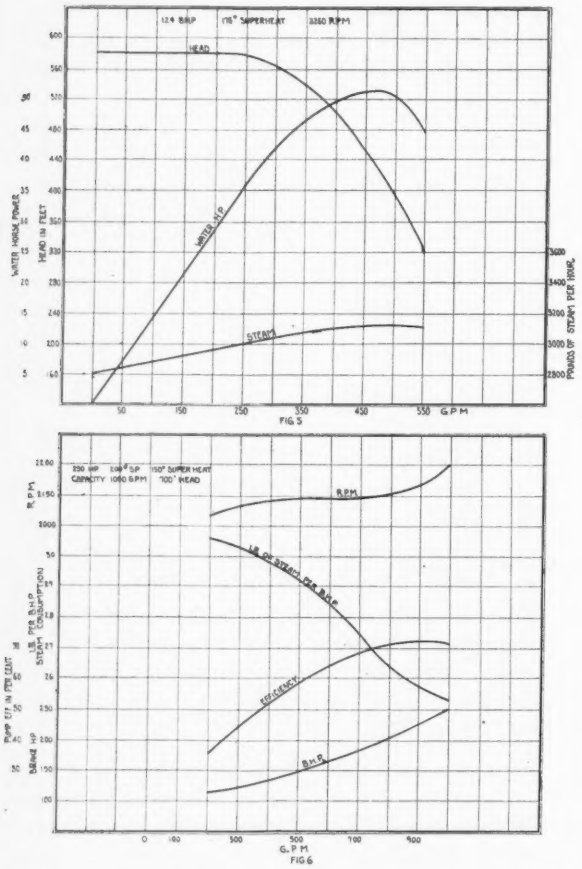


FIG. 5. TEST RESULTS OF A 3-IN., THREE-STAGE, TURBINE DRIVEN BOILER FEED PUMP

FIG. 6. EFFICIENCY CURVES OF A 6-IN., THREE-STAGE, TURBINE DRIVEN BOILER FEED PUMP

a properly packed stuffing box is one which has a small leak in it constantly. It will be observed that practically all pumps have a tapped opening in the bearing housing for this purpose.

Operation

1. Be sure that pump and motor are properly alined.

2. Be sure that the bearings have been washed with gasoline or kerosene and bearings refilled with a good grade of oil.

3. Be sure that the pump runs in the right direction; this, on most pumps, is indicated by an arrow cast in the pump casing.

4. Prime the pump; make sure that all air is out of the pump and pump casing.

5. Close the discharge valve; never start a pump up with the discharge valve open.

6. Start the pump up; remember that a centrifugal pump should never run when it is empty of the liquid to be pumped. If the pump has been properly primed and all the air is out, as the pump comes up to speed, the pressure should be built up and when the pressure has reached its normal shutoff head, the discharge valve may then be open to give the capacity desired.

7. Never draw the packing glands up tight; always allow a little leak to be present.

8. Be sure that the water seal rings are being supplied with fresh clean water, even if it is necessary to pipe the connections to some external source of supply.

In conclusion, let us take up the rumor story that centrifugal pumps are not reliable. This, like all other rumor stories, is generally based on anything but facts.

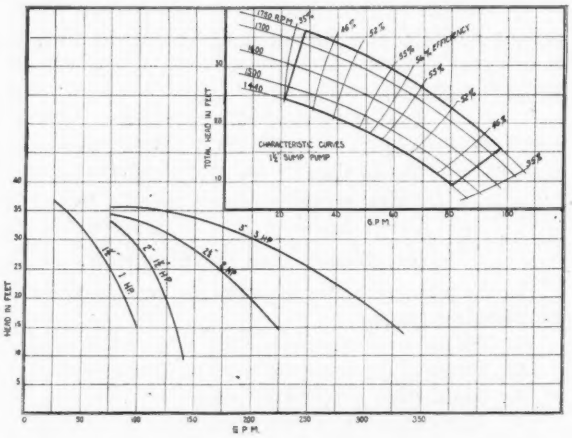


FIG. 7. HEAD CAPACITY AND CHARACTERISTIC CURVES OF SUMP PUMPS

To refute this story, some extensive records were kept and a 3-yr. period of some 300-odd pumps of all classes was taken up in this paper. The tables given herewith show the results obtained:

		Number of Cases of Trouble	Per cent of Total Cases
1.	Motor troubles	9	26.5
2.	Hot bearings	7	20.5
3.	Broken shaft	1	2.9
4.	Obstructive hyd. bal. pipe	3	8.8
5.	Porous castings	2	5.9
6.	Leaky gaskets	1	2.9
7.	Wrong pump sold	4	11.8
8.	Misc. factory errors	7	20.5

Motor troubles were caused by wet coils and low voltage with one case of defective insulation. The hot bearings were caused by the pumps getting out of line during shipment and not being relined, or from failure to clean out bearings and fill with clean oil. The broken shaft was caused by a structural defect in the metal. Obstructive hydraulic balance pipes was caused by dirt in the line getting into the pump casing. Porous castings developed after a short use, due to some dirt in the iron. The one case of leaky gaskets was due to the fact that the pump was not used for several months after leaving the factory, and the packing dried out.

In four cases of trouble it was found that the salesmen had obtained the wrong data, consequently the wrong pump was supplied. There were seven cases of strictly factory errors, which consisted mostly of failure to tap

drain holes, one case of a blocked volute and two cases of wrong calculation of impeller sizes.

These results, when reclassified according to the pump classification, show the following table:

	Motor		Pump	
	Cases of Trouble	Per cent Total	Cases of Trouble	Per cent Total
Class 1 ..... Double Suction	2	5.9	7	20½
Class 2 ..... Multi-stage	4	11.8	3	8.8
Class 3 ..... Sump, Pumps	1	2.9	12	35.2
Class 4	2	5.9	3	8.8

These tables show conclusively that centrifugal pumps are reliable and dependable.

Negotiating Purchase of Stokers

CONSIDER SPECIFIED APPLICATION; CALL UPON MANUFACTURER FOR NEEDED DATA. BY H. N. SCOFIELD*

PURCHASING mechanical stoker equipment involves the entire combustion system and frequently means a radical change in method of operation throughout the boiler plant. Stoker buying falls into two classes; the buying of equipment to replace hand firing or existing stokers and the buying for entirely new plants.

In the former case, aside from the increase of boiler output and the increased combustion efficiency, the prime object in the average installation is labor saving. For that reason the engineer ought to make a careful investigation of the application of his chosen stoker to the existing conditions before closing the contract. This should cover the nearest approach to the ideal layout. Frequently comparatively small changes so far as the total cost of installation is concerned would make permanent savings in operation. For instance, often the boiler room floor can be lowered, making greater combustion space available. Breechings can be made tight at small expense, increasing the available draft, resulting in the possibility of greater boiler output. Ash handling arrangements can be worked out by the utilization of modern equipments, such as monorail hoists, that will pay a large return on the investment. This also applies to coal handling facilities. The conscientious engineer will consider the desirability of these things during the course of the negotiation of the purchase of stoker, as the results obtained from the stoker are vitally dependent on these features.

Practically all stoker manufacturers build their product in a variety of sizes and with careful thought as to the load conditions, the probable increase in load and to the varieties of coal that will be available for use, the engineer can select the size of stoker best suited to these conditions. He should not be induced by consideration of competitive prices to reduce the size of the stoker or the auxiliary equipment. When it is considered that many times the original cost of the stoker is represented by the fuel burned on the stoker yearly, it is evident that a saving in initial cost of the stoker, which is almost invariably reflected in the efficiency of operation as well as the capacity of the installation, is poor economy indeed.

*Stoker Sales Manager, American Engineering Co.

It is true that in many organizations the purchase of large equipment such as stokers is finally decided by one man but the successful operation of the equipment depends upon many of the operating force who also should be converted to the merits of the equipment he has selected. This is because a stoker, more than almost any other piece of equipment in the power plant, is subject to the human element for satisfactory operation. A favorable attitude toward the stoker on the part of the operating organization will insure a satisfactory installation.

Compared with most other power plant equipment, a stoker is subjected to extremely severe conditions. As a conveying equipment it handles the same amount of material as the coal and ash handling equipment. In addition it handles these materials at intensely high temperatures. Considering these conditions, the maintenance of a modern properly operated stoker is remarkably low; the engineer, however, should obtain from the manufacturer a frank statement as to what the amount of maintenance is expected to be and arranged to order the parts most likely to need replacement to be shipped with the stoker contract order. He will readily appreciate that the original manufacturer can supply parts to far better advantage than a local foundry. This is due to the proper fit of parts and the improvements in details of construction made available if the parts are being purchased from the stoker manufacturer.

For the new power plant the designing engineer should call upon the manufacturer for the recommended setting heights, stack sizes and air duct sizes. The increasing tendency to use long stokers making possible a great increase in amount of fuel burned per foot of width of setting has given the designer great latitude in the selection of boiler and stoker equipment. For instance, at the 59th Street Station of the Interboro Rapid Transit Co., New York City, by the wise selection of boiler and stoker equipment, units are being installed to develop 4800 hp. which occupy no more floor space than the original installation which developed only 900 hp. The manufacturer can furnish information on such modern installations which should be of value to the designing engineer.

In negotiating the purchase of a stoker the engineer should avail himself of the services of the stoker salesman who usually is a technically trained engineer and has had stoker operating and erecting experience. He has back of him not only the experience of his particular company but also the carefully classified and worked out recommendations of the Stoker Manufacturers Association. This association comprises all the larger manufacturers of stokers in the country. Therefore the stoker salesman is in a position to render real service to the purchaser.

NEW YORK STATE leads all the others in the amount of water power development, the extent of the utilization being 1,300,000 hp. The largest single development is at Niagara Falls. The second state in the use of "white coal" is California where something more than 1,100,000 hp. are developed. There is a big gap between these figures and those for Washington, which occupies third place, using 454,000 hp. Maine is fourth, with a few thousand less horsepower, and Montana is fifth, with 344,000-hp. development.

WHEN a man is in trouble, any rumor is sufficient to complete his ruin.

Methods for Applying Lubricants

LUBRICANTS SHOULD BE APPLIED IN A MANNER WHICH IS CONSISTENT WITH THE IMPORTANCE OF THE PART WHICH IS TO BE LUBRICATED

METHODS BY which lubricants are applied to machinery are important not only from the standpoint of the operation of the machinery but also from that of the saving of lubricants. A careful selection of an oil will not guarantee that all lubricating troubles are over, in fact they may still persist, unless careful attention has been given to the manner in which the oil is applied.

On almost all machinery there are moving parts of comparatively small importance where the most simple method of lubrication would be justified and, on the other hand, there are certain moving parts where the best methods obtainable must be used.

In general, lubrication systems may be divided into two classes: (1) systems where the lubricant must be applied to external bearings and (2) systems where the lubricant must be applied to internal bearings or surfaces.

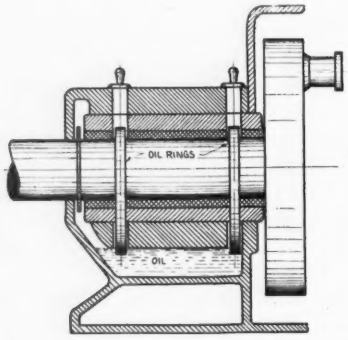


FIG. 1. RING-OILED BEARINGS ARE BUILT WITH AN OIL RESERVOIR IN THE BASE

In power plant work, the former class of systems is best illustrated by engine bearings which are not inclosed by parts of the engine which hold steam. The internal bearings of a steam engine would include the piston, cylinder walls, valves and stuffing-boxes.

Lubrication of external bearings by hand has little to recommend it except that it is simple. Its disadvantages are that it is wasteful and unreliable because absolute dependence is placed upon the operator to apply the lubricant at proper intervals. Hand lubrication is necessarily an intermittent method and it should, therefore, be limited to small units and to bearings which have a limited motion and light bearing loads. The tendency of most operators is to neglect a bearing which must be lubricated by hand and, when they do use the oil can, the tendency is to flood the bearing.

Many steam engines which operate at medium or high speeds are lubricated by what is known as the splash system. In this system an oil reservoir is provided in the base of the enclosed crank case. The oil is maintained at such a level that the crank dips in it to a depth of about 2 in. As the crank revolves, it throws the oil onto the crosshead shoes and guides. The splash system also lubricates the crankpin. Located along the sides or at the end of the crank case are troughs which gather the oil as it is splashed up and drain it through distributing pipes to the main bearings and the eccentric straps. This oil after having served its purpose on the bearings drains back into the crank case reservoir where it is again thrown up by the crank disk.

This system is open to the objection that small quantities of condensed steam will work their way into the crank case and will emulsify with the oil. Frequently a stuffing-box is placed in a dividing wall which is located between the rod stuffing-box and the guides, in order to keep water out of the crank case. In any event the crank case should be provided with an overflow or drain by means of which the oil or water can be removed.

Ring-oiled bearings are effective and reliable in that they feed a liberal amount of oil whenever the shaft is rotating. Bearings of this type are provided with an oil reservoir in the base. The shaft is encircled with several rings which are guided by slots cut in the bearing cap. These rings dip in the oil stored in the bearing base and, as the shaft rotates, it causes the rings to rotate and thus bring oil to the top of the shaft where it spreads to the bearings. Occasionally the rings are replaced with loops of chain but the ring is to be preferred because it has no joints. The chain may open with the result that the bearing will not receive oil until the condition is noticed and repaired or the bearing has been damaged.

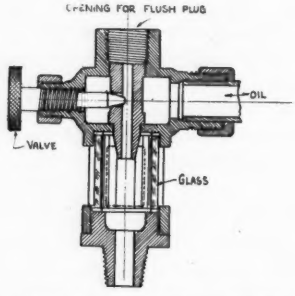


FIG. 2. ALL IMPORTANT OIL LINES SHOULD BE EQUIPPED WITH A SIGHT FEED

In either the splash system or the ring-oiled bearing, ample oil must always be in the reservoir and periodically, say once every 6 mo., the reservoir should be thoroughly cleaned out and new oil supplied.

DROP-FEED METHOD OF LUBRICATION

External bearings of small units and some of the less important bearings of intermediate and large units are lubricated by the drop-feed method. In this case, the lubricator usually consists of a container, which is preferably made of glass, from the bottom of which the oil flow is regulated by means of a needle valve, which is adjustable so that the rate of oil feed can be varied. Located just below the oil container and opposite the discharge from the needle valve is a sight-feed glass through which the operator can see the rate of oil feed.

This method of lubrication is more uniform than the hand method but requires rather close attention to see that the container does not run dry. This type of lubricator will feed more oil when filled to the top than when it is nearly drained. Drop-feed oilers are generally mounted

directly over stationary bearings or may be used in connection with wiper cups or telescopic oil pipes for crosshead pin and eccentric lubrication. They may also be used in connection with pendulum and telescopic lubricating devices as used for the lubrication of crankpins.

Gravity Circulation of Oil

One of the most popular and effective systems for bringing a continuous supply of oil to the external bearings of an engine or turbine is known as the gravity circulation system. It consists, essentially, of an overhead tank from which oil flows by gravity to the various points to be lubricated. The oil, after passing through the bearings, drains to catch basins under the various bearings. Collector pipes carry the dirty oil from these basins to some kind of an oil purifying device, such as a filter.

From the filter the oil is picked up by a pump which again delivers the clean oil to the overhead tank where an indicator or gage glass shows the oil level. A sight-feed glass with valve control is located in the oil line to each bearing so that the rate of oil feed can be observed and regulated to meet the requirements of each bearing.

Advantages of this system are that a continuous and generous supply of oil can be fed at all times. Further, the system readily lends itself to the use of a filter or purifier so that the oil can be reclaimed and returned in good condition to the bearings. New oil need be supplied only to make up for leakage and evaporation. The location of the purifier should be below the level of the engine or turbine bed so that dirty oil will drain to it by gravity. The overhead tank can be located at almost any point to suit building conditions.

Objections are sometimes raised against this system because it is claimed that the oil will feed faster when the overhead tank is full than when it is nearly empty. This, however, can be overcome by close attention to the supply of oil to the tank or by operating the return pump continuously. This system readily lends itself to the supplying of oil to the external bearings of more than one unit. A modification of the system, when used for one unit, is to have the return pump operated direct from the main engine, so that the system will be in operation whenever the engine is running.

External bearings may also be lubricated by what is known as the forced-feed system in which the oil is delivered to the bearings under a positive head of 5 to 15-lb.

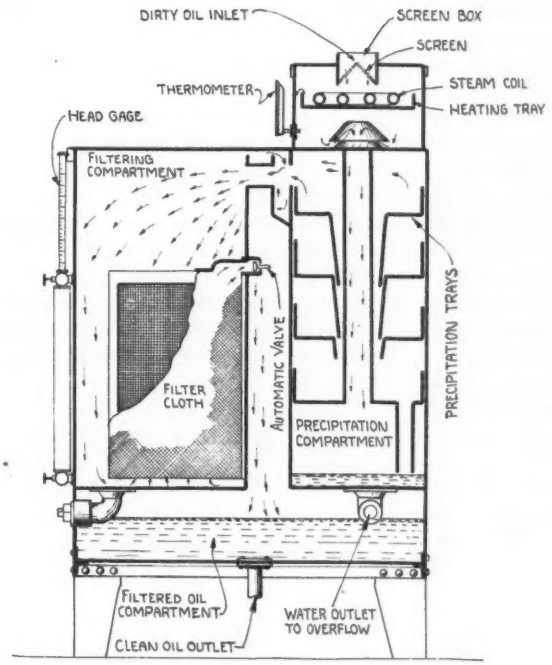


FIG. 6. CROSS SECTION OF AN OIL FILTER

pressure. All the dirty oil drains to a reservoir in the base of the engine from which it is picked up by a pump and delivered through pipes to the main bearings. Since the crank shaft is hollow, the oil flows through the shaft to the crankpin and eccentric.

Methods of Purifying Oil

Two methods have been devised by means of which dirty oil may be purified, these are known as, (1) the filtering system and (2) the centrifugal system. In the former, the oil is purified by screening, precipitation and filtering. In the latter system, the impurities in the oil are removed by the application of centrifugal force.

Operation of the filter shown in the accompanying illustration, Fig. 6, is as follows: the oil to be filtered enters at the top through the removable strainer box where large particles of foreign matter such as waste, etc., are removed. Located just below this strainer is a heating coil and tray over which the oil must pass in a thin sheet.

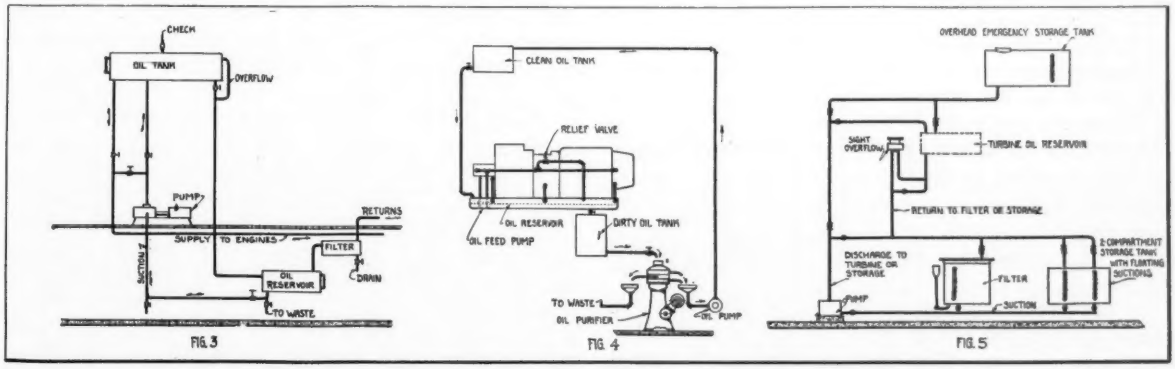


FIG. 3. GRAVITY CIRCULATION SYSTEM USED FOR EXTERNAL BEARING LUBRICATION
FIG. 4. CENTRIFUGAL OIL PURIFIER INSTALLED WITH THE BATCH SYSTEM OF OIL PURIFICATION
FIG. 5. CONTINUOUS BYPASS AND BATCH SYSTEM OF LUBRICATION AND OIL PURIFICATION

From the heating tray the dirty oil flows down through a pipe to the bottom of the precipitation-tray compartment. These trays are staggered so that the oil in passing upward follows a zig zag course. The trays are open around the down-take pipe so that impurities may settle to the bottom of the compartment. From the top of this compartment the oil flows over into the filter compartment in which is located a battery of cloth covered filters. The oil passes through the cloth filters and discharges from the top of the filters into a center compartment which is used for the storage of the pure oil.

Gage glasses and overflow drains are located in the precipitation-tray and filted compartments. Thermometers are fitted to the heater-tray and pure-oil compartments.

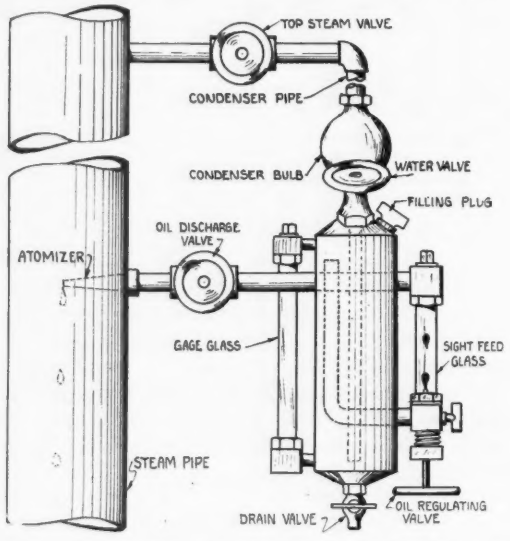


FIG. 7. HYDROSTATIC LUBRICATOR CONNECTED UP TO STEAM LINE

The filter just described is known as the continuous type; there is another type made which is used for batch filtering, in which a definite amount of oil is placed in the filter and filtered in one batch.

Mechanical separation of the impurities from an oil is accomplished by means of the centrifugal purifier.

In cases where an oil has become acidified through use, a third method of oil purification must be employed. In this case a chemist should analyze the oil and recommend a treatment; the cause for the acidulation should be found and remedied.

Methods of Using Purifiers

In general there are five ways of maintaining the purity of oil. These are, (1) make-up, (2) sweetening, (3) batch, (4) continuous bypass and (5) the continuous method. In the make-up method, only such oil as is lost by evaporation or leakage is added to the system. This may be done at rather long periods and once every 6 mo. or so the entire system should be cleaned out and new oil put in. The old oil may be purified when convenient and used again at a later date.

In the sweetening method, a part of the old oil is periodically removed and an equal amount of fresh oil is put into the system. This amounts merely to a partial dilution of the impurities in the system. In the batch method, the entire system is drained of oil and replaced with fresh oil, which requires the shutting down of the unit. The dirty oil can, of course, be purified and used again when the next cleaning is necessary.

Probably the most favored and most satisfactory method is that of the continuous bypass system, where a part of the oil in the system is continually passing through a purifier, thus providing a continual sweetening.

Continuous treatment involves the purification of the entire quantity of oil in the system each time that it is handled by the pump. Although this system is ideal, the extra equipment required is costly and requires considerable space, therefore it is seldom used.

Appliances used for the lubrication of internal bearings are, (1) hand pumps, (2) hydrostatic lubricators, (3) mechanical forced-feed lubricators. The first method, that is by the use of a hand pump, is seldom used, although a hand pump should be placed on the oil supply pipe over every engine so that it can be brought into service on short notice. It is essentially a stand-by arrangement.

Hydrostatic lubricators are an effective means of introducing oil into the steam for general cylinder and valve lubrication. Their successful operation depends not only upon their proper manipulation but also upon the form of

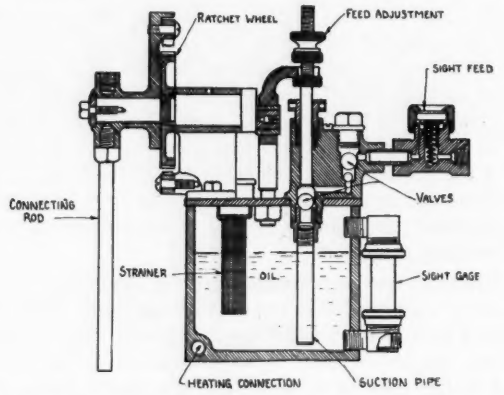
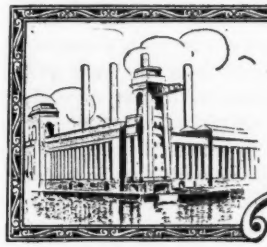


FIG. 8. CROSS SECTION OF A MECHANICAL FORCED-FEED LUBRICATOR

spoon or quill to which the oil is delivered in the steam pipe. The location of the quill in the steam pipe is also of great importance. This type of lubricator must be stopped when the engine is shut down, otherwise it will continue to feed and thereby waste much oil. The rate of oil feed depends upon the viscosity of the oil and will, therefore, change with different room temperatures and with each time the lubricator is filled. In winter it will often be necessary to heat the lubricator before it can be started. The condenser bulb must always be filled with water, otherwise steam will enter the reservoir and churn the oil so that its height cannot be read on the gage glass.

Mechanical forced-feed lubricators are positive in their action and are arranged to stop automatically when the engine stops. These points make them desirable for internal lubrication. Multiple-feed lubricators of this type are of distinct advantage when supplying oil either to a number of points on a simple engine or to the two cylinders and valves of a compound engine. The lubricator may be installed at any convenient place where it can be driven by the engine and where the sight feeds can be easily seen and the filler plugs reached. A check valve should be placed in each oil line near the part which is to be lubricated. This prevents steam backing up into the lubricator or a vacuum from drawing the oil out of the lubricator.



LETTERS DIRECT FROM THE PLANT

Novel Feed Water Heater

M. M. BROWN'S article on page 351 of the March 15 issue describing an arrangement for heating feed water recalls to my mind a contrivance which came to my notice some years ago and which had been palmed off on an unsuspecting mill owner. Whereas Mr. Brown was able to show an improvement with his arrangement, the inventor of the device I have in mind received a substantial fee for his work but was unable to show any improvement in the results obtained.

To begin with the small four-valve engine, which constituted the motive force of the mill, exhausted through a perfectly good, up-to-date closed heater of a size sufficient to heat the feed water to a temperature of 210 deg. F. The feed water was taken direct from a nearby well and pumped through the heater direct to the boiler.

In attempting to effect a saving in the cost of operation of the plant, the promotor of the new steam and fuel saver first dug a hole in the ground and made a kind of cistern. The exhaust line from the heater was run to this cistern and installed as shown in the accompanying sketch. The free end was turned up and an umbrella of galvanized iron was supported over it. Cold water was pumped through a series of small holes in a pipe at the exhaust elbow in such a way as to provide a sort of rain or spray over the exhaust outlet. The idea was of course to condense some of the exhaust and at the same time heat the feed water, which, considered by itself, is quite a desirable feature.

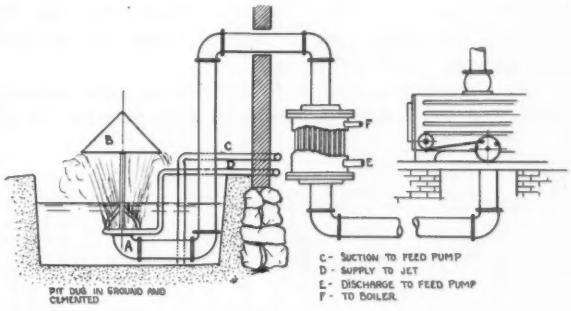
As far as the mechanics of the arrangement were concerned, the mingling of the exhaust and the spray functioned quite satisfactorily—for a short while. Then, through some misadventure, the water in the cistern rose too high and submerged the end of the exhaust pipe, with the result that the umbrella suddenly lost its moorings and shot skyward.

After this mishap the exhaust line was raised somewhat and an overfloat was installed at the proper heights in the cistern; there was no further difficulty.

In spite of this improvement, the operating engineer reported that he was unable to heat his feed water to a higher temperature than had been the practice before the new equipment was installed. Strange, is it not?

In the old days (this happened almost 30 yr. ago) most engineers in small plants did not seem to know some of the fundamentals of physics and thermodynamics; they did not seem to know, for instance, that water could not be heated above a certain definite and fixed temperature by steam at atmospheric pressure. Because of this, when the promoter of efficiency made the statement that by raising the water temperature 50 or 60 deg. before it entered the heater the final temperature leaving the heater would be just that much greater, there was none to dispute him and his system went in.

Well, the story goes that the mill company paid him about twice per hour what they had been paying the chief engineer and when he, the engineer, said that he was burning as much coal as ever the company accused him of being jealous and attempting to discredit the other's achievement. They claimed that they were using the exhaust steam twice, once in the heater and once in the spray well and the steam that formerly went to waste was being returned to the boilers, consequently if they were not saving coal, either the engine was doing more work or the engineer was not a fit man for the job.



ARRANGEMENT FOR INCREASING FEED WATER TEMPERATURE

Obviously an understanding of two simple but fundamental truths would have saved all this outlay of capital and the resulting hard feelings. It seems that somewhere in the past I recall a statement to the effect that in any saturated vapor there is a very definite relation existing between pressure and temperature; in the case of steam at atmospheric pressure, this temperature is 212 deg. F. and can be no higher. Another statement or law or axiom, I recall it as the second law of thermodynamics, says, in effect, that heat can not be made to flow from a lower to a higher temperature or heat level.

From these two statements should it not be obvious that water or anything else, for that matter, can not be heated above 212 deg. F. by exhaust steam at atmospheric pressure?

TOM THUMB.

Heavy Firing of Steam Boiler Furnaces

ON PAGE 380 of the issue for April 1 appears, under the caption, "Some Hints for Boiler Firemen," the following item: "Some firemen are in the habit of putting on a heavy charge of coal, thinking that the more coal fired at once, the longer they will have to rest between charges. This procedure is absolutely wrong."

If this were absolutely wrong, the firemen would soon find it out and practice the easier way. The fact is that the easiest way for a fireman is to fire a heavy charge of coal and then sit down until another one like it is required.

He will shovel more coal in the long run but he can do it much more easily than if he fired light and often.

A certain machine shop, with which I am familiar, was run by one boiler and one engine. The engineer was the fireman also. He put on a heavy charge of coal and after allowing it to burn for about an hour he put on another. It required a certain amount of coal each week.

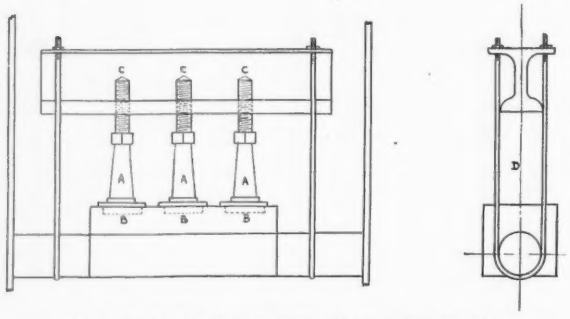
The proprietor became dissatisfied with this engineer, discharged him and hired another. The new man believed in firing light and often. I have watched him as he put on two small shovelfuls of coal at a time. It was scarcely worth while to shut the furnace door because it was opened so soon again. The result was that the saving of coal amounted to 25 per cent. The labor of running that plant was greatly increased but while these items could not be disputed, they were not appreciated.

New Haven, Conn. W. H. WAKEMAN.

Repair for Hydraulic Pressure Pump

IN THE plant where I am employed, we have a single-acting triplex pressure pump, size 2 by 6 in. This pump is working against a pressure of 500 lb. per sq. in., and is used to run our bonding presses. Some time ago, the thread in the pump, over the suction valves, got stripped, and the caps would not hold.

This pump was repaired by first having some castings, made 2 in. in diameter on one end 1¼ in. diameter on the



REPAIR FOR STRIPPED THREADS ON PUMP CAP

other and 4 in. long, as at A in the sketch. Then we put the caps in the lathe and turned the thread off at B. Next we took a rail and drilled and tapped it, as at C for 1 in. bolts, then took a ¾-in. rod and threaded it on both ends and bent it as at D. After putting gaskets under the caps and screwing out on the 1-in. bolts at C we had a tight job and the pump is still doing good work.

Gardner, Mass. A. A. WILLIAMS.

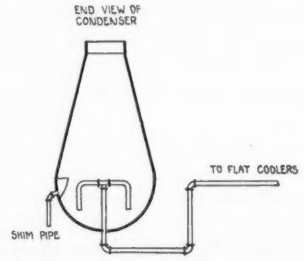
Larger Exhaust Pipe Cures Oil in Ice Problem

NOTWITHSTANDING that most of the development in the ice-making field during the last few years has been in connection with raw water systems, distilled water ice is yet being made. In some localities the distilled water plant is the only one that can be operated with success because of the hardness of the water available.

I find a great many people make the big mistake of thinking that anybody—any kind of a makeshift engineer—can be successful in the manufacturing of distilled water ice. Sometimes this can be done for a while until something goes wrong and then usually everybody is up in the air hunting trouble.

In a town where the water was exceedingly bad, containing quantities of salt drainings from the wells of the oil fields which ran into the river, we had to depend on river water. I was first at the old plant, two plants being located in the town, and there I learned how to use the water, and made good ice all the time with some exceptions. When we had too high water in the boiler, we got a little white in the ice.

Later, however, I was employed to take charge of the new plant which was a modern plant of 90 T. capacity. I was told by the man who financed the plant that there was something wrong with it. The man who designed and



DISTILLED WATER CONNECTION TO CONDENSER WHICH LEAVES SEDIMENTS IN BOTTOM

managed the plant was supposed to be an expert engineer but there had been no good ice made in the plant. To make any changes in the plant was contrary to the wishes of the designing engineer but I went about the matter carefully and operated the plant about 10 days before I reported on what I wanted to do.

The big trouble was that the oil could not be separated from the distilled water. All kinds of oil were used and used sparingly, still the water had to be filtered through cloth and paper and at times could not fill over 10 cans until this paper and filtering cloth would have to be renewed.

Tubular type condensers were in use. I soon located several places likely to give trouble. The oil trap in the exhaust line was changed and the reboiler had some wrong pipe connections, but the main reason was found to be that the exhaust pipes were too small and the velocity of the steam was so great that the oil vaporized to such a degree in the steam that it could not be arrested until after it reached the condensers where it was cooled.

I changed the pipe to a larger size, took out the filter between the forecooler and can filler and I never saw better ice made in any plant than we got here.

In the accompanying sketch is shown how the outlet pipe of a flash condenser which was making bad ice was connected up to give pure water. The trouble was that when the water was drained too low in the condenser it would become druggy and show red in the cores of the ice from the sediment in the bottom of the condenser and when it was up, a great deal of oil was carried over the water to the flat coolers and on through the system. The trouble was remedied by using a tee on the distilled water pipe about 14 in. above the bottom of the condenser, inserting two bent pipes as shown in sketch to protrude downward into the water and having a ¼-in. pipe to run from the top of the cross up and out of the condenser to act as a vent pipe and overcome the water from siphoning out too low.

This arrangement will not allow all the water to drain out of the condenser and the pipe can be turned up by the use of 90-deg. elbows to form a water level that keeps the water up over the end of the bent pipe. This condenser acts as reboiler as well as condenser and has a skimmer attached to the side of the walls of the condenser. By closing the water in the outlet line in any convenient place this will allow the top to skim off and run out through another pipe connected with a 45-deg. elbow.

Corpus Christi, Texas. R. S. MARTIN.

Doing Away with Licensed Firemen and Engineers

REPLYING TO Mr. Clark's article on page 449 of the April 15 issue, it seems that he has not studied the license exemption clauses of the revised Massachusetts Engineers' Firemen's License Laws thoroughly. This law states that no state license is required for engineers or firemen operating boilers on locomotives, boilers under the jurisdiction of the United States, boilers or engines used in private residences, boilers and engines used for agricultural purposes only of less than 9 hp., boilers for apartment houses of less than 5 apartments. And boilers used for heating purposes exclusively which are provided with a police lock pop safety valve set to blow at 15 lb. pressure.

It is the general opinion of engineers and firemen in Massachusetts that any and all persons operating any boiler regardless of size should be licensed. The license shows that they have passed an examination as to their fitness to have charge of and operate steam boilers or engines. In case of accidents, causing injuries, if due to carelessness or neglect on the part of the attendant, his license can be revoked to prevent him from causing another accident. I know of one engineer who wrecked five engines in as many power plants for the same corporation before a system of employment was devised to prevent this destruction of property, yet his license was not revoked because no complaint had ever been made to the boiler inspection department, as nobody was injured in these engine wrecks. Yet he has not been found or his license taken up on account of his migrations. Many have been revoked or suspended for this reason.

I have heard of a heating boiler in a lodging house (operated by one of the maids) which had been insured. The insurance inspector found the boiler in operation with no water in sight in the gage glass and but little in the boiler after he had drawn the fire. This boiler came under the exemption clause in regard to apartments of less than five flats and private residences and nothing could be done to prevent such operation. Agricultural boilers have exploded with loss of life and property and serious fires caused by careless operation of heating boilers in apartment houses and private residences.

Employers are not generous in hiring skilled engineers and firemen at high salaries when anyone can operate their boilers at less expense, when the state inspectors are required to vouch for its safe condition and the condition of the safety valve which has a police lock on it. It may not be the right spirit as regards public safety, but in this case I see no violation of the license law. As the boiler is used for heating purposes exclusively and has a lock pop police safety valve on it, anyone can operate it, as this is the way the law reads and applies in such cases.

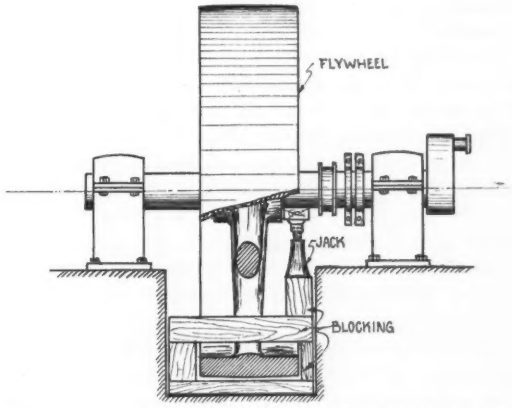
It is not necessary that the attendant be able to make even the slightest repairs if the employer can send to a local shop and secure boiler makers, steam fitters and other skilled mechanics to do the repair work for a few hours pay plus cost of material. In the case cited (a mill plant) there are usually such mechanics in the plant. As far as public safety is concerned, the Employers' Liability Insurance Law protects him in case of accidental injuries to employes or others.

While I fully appreciate Mr. Clark's position in this case, I think he has not considered the employer's side of the case, which would be a fair way to look at it. It is not a licensed engineer's or firemen's position according to the law.

Cambridge, Mass. R. A. CULTRA.

Jacking Up an Engine Shaft

IN A lighting plant, the main bearing on one of the Corliss engines had been running hot on account of the poor oil which we had been obliged to use while awaiting a delayed order of new oil. In order to remove the bottom shell in the bearing for scraping, it was necessary to raise



METHOD OF PLACING BLOCKING IN A RESTRICTED SPACE FOR JACKING UP AN ENGINE SHAFT

the shaft ½ in. There was not sufficient space under the crank-disc, to allow us to use a jack and the time the engine could be spared was too limited to allow for stripping the eccentrics.

There was a space of 6½ in. between the edge of the flywheel rim, and the size of the wheel-pit, on the side next the bearing. A block, 6 by 12 in. was laid in that space on the concrete floor of the wheel-pit and other blocking, as shown in the sketch, was placed. A screw-jack on an upright timber raised the shaft the desired amount to enable us to roll out the bottom shell of the bearing.

Utica, N. Y. M. M. BROWN.

Unusual Engine Foundation

IN 1888 I sold a 19 by 34 by 44-in. tandem compound engine to be installed in a building which was once used as a flour mill operated by water power. In setting up the foundation for this engine, we ran into a peculiar situation when we came to placing the footing for the outboard pillow block. The masons encountered great quantities of water, which was found to be running water from the old sluice that had not been filled up, and were unable to make their brick work hold. They had tried pouring cement in the pit but it was all immediately washed away.

To prevent this washing away, we put about a dozen bags of Portland cement into the hole, unopened. By the next day the cement had set and it was possible to proceed with the brick work.

This engine was run for over 12 yr. in this location without any sign of settling of the foundation and the shaft was in perfect alinement all this time.

Milwaukee, Wis. WM. T. DOYLE.

Rotary Pumps Adopted for Hard Service

IN COMMENT on an article in the April 1 issue which compares rotary with centrifugal pumps, may I call attention to the following instances where rotary pumps have been selected after test and consideration by some of the largest engineering departments?

In 1917 the Navy Department ordered an official test of our pump at the Experimental Station in Annapolis and the test was carried out on a 500-gal. pump against pressures up to 300 lb. The pump was approved for all navy vessels where the rotary type pump was being used. A second test run in 1920, pumping oils at from 65 to 400 lb., resulted in a second approval.

The Navy has used rotary pumps for port service boiler feed pumps to work against 350 lb. pressure and fuel oil service pumps to work against 300 lb. pressure.

War Department specifications for hopper dredges, in 1922, called for rotary pumps of which 76 are now being installed on four vessels. Also a 24-in. pipe line dredge is being equipped with 12 pumps of rotary type and another with 8 such pumps.

Standard Oil Co. of New Jersey has just placed in service a Diesel-engine-driven barge which has 7 rotary and 2 centrifugal pumps for circulating water to the engine jackets. They are also using rotary pumps for handling gasoline and oil on the barges in the Ohio district as well as for jacket water.

United Gas Improvement Contracting Co. of Philadelphia has recently ordered two rotary pumps for hydraulic duty, one for 65 gal. a min. Foamite-Childs Co. has ordered 8 twin sets with electric and gasoline drive and some dual drives in units of 100 to 800 gal. a min. per pump.

It is evident from the above list that people who do not buy without investigation are using rotary pumps largely, for handling water, gasoline and other liquids which are not considered as lubricants.

JOHN A. HENSE,

New York City. Northern Fire Apparatus Co.

COMMENTING on the foregoing, Wm. F. Traudt, author of the article in question, says in substance: I made no reference to a limitation on the pressure against which a rotary pump might deliver and the use of such pumps for handling lubricating oils does not disprove my statement as to their use for such liquids as salt brine and vinegar.

As to the tests at Annapolis, it is to be assumed that the pump was tested as a boiler feed pump, handling hot water at 300 lb. It would be interesting to know whether this was a short test or an endurance test extending over say 3000 hr., or a year's service.

The point that I wish to bring out is that where parts are in metallic contact and in motion relative to each other, whether in a pump or other mechanism, durability depends upon suitable lubrication and it seems obvious that salt brine or vinegar or even water will not be as satisfactorily handled with a pump of the rotary type as with other types.

The phrase "any form of gear type rotary pump" was used because comparison was made with the transmission gears of an automobile. It might as well have been "any form of rotary pump." WM. F. TRAUDT,

Taber Pump Co.

Isolated vs. Central Power Plants

I AM NOT a staunch supporter of the isolated or private plant; I believe in both the isolated plant and the central station and these are my reasons:

My stand lies in a combination of these. All of us have figures placed before us from time to time that work out nicely mathematically and tend to prove, for instance, that it would be more profitable to throw our present private power plants into the junk heap and purchase central station power. Again, the gentleman who sells small plant machinery is prone to come around and hypnotize us with more figures that show central station power to be "bunk" and unprofitable in the extreme.

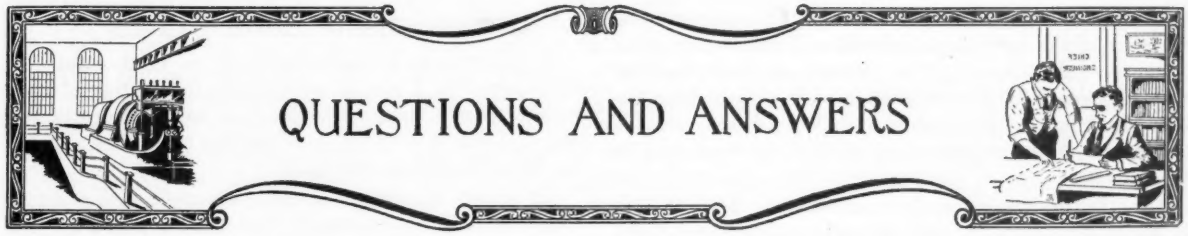
It is no easy matter to solve a problem of this kind with cold figures, for there are so many things that enter besides mathematics. Much depends upon the man behind the engine. A poor fireman is often mighty expensive; he can waste his wages over and over through improper care of the boiler or boilers. Where coal is burned, he can ruthlessly waste it and get the boilers into such poor condition that their life will be materially shortened: boilers are expensive. Where the plant is so small that one man can take care of the entire power end himself, it usually pays to pay a little more than the average wage and get a good man. The extra amount paid him will be returned in multiple.

Sometimes, true enough, the central station solicitor is right in saying that central station power would be best. Where power is seldom used, where the amount required is small, where an extra man would have to be employed to run the power plant and where his wages would be a burden, it is best to purchase central station power if it is available.

There are so many different ways of figuring—with steam, gas, gasoline and water power—that they must all be carefully considered before deciding on any one and good judgment must be mixed in with the figures, to care for the personal equation of the man you are going to put in charge.

When a man comes around with actual figures and tries to influence you one way or the other, you needn't necessarily believe his figures to be absolutely correct. Don't call him a liar, though, for he may be earnest, serious and truthful. There may be some good meat in what he says but there may be better meat in what the other fellow will tell you, or in what you can dig out for yourself through manufacturers' catalogs, magazine articles, advertisements, letters, etc. The power matter is well worth giving careful study, for much good money can either be saved or wasted there. N. G. NEAR.

TO FIND the capacity of a cylinder in gallons: Multiplying the area in inches by length of stroke in inches will give the total number of cubic inches; divide this amount by 230 (which is the cubical contents of a U. S. gallon in inches); the product is the capacity in gallons.



Ligament Efficiency

How SHOULD the efficiency of the ligament on the shell of a cross drum type boiler be calculated? J. J. Z.

A. J. J. Z., who inquires for directions covering the calculations necessary to determine the efficiency of the tube sheet ligament of a cross drum type boiler, probably had in mind some particular boiler, that is, an existing installation where diameters, thicknesses and pitches could be actually measured but we believe a better understanding will result from the consideration of all of the factors bearing on the subject.

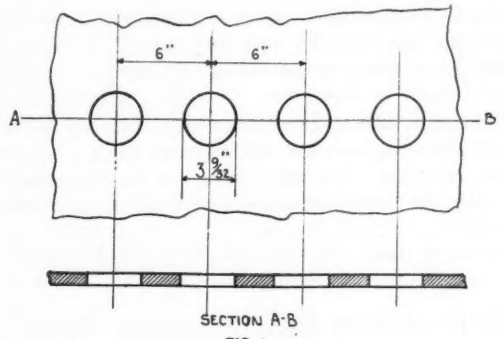


FIG. 1

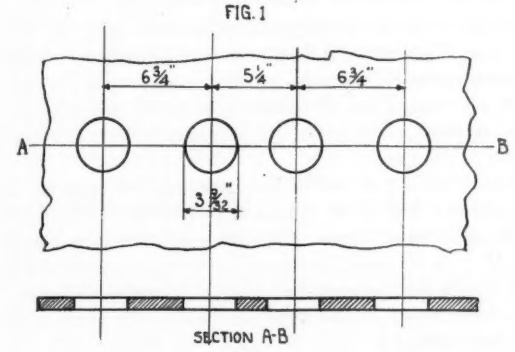


FIG. 2

FIG. 1. EVENLY SPACED TUBES IN SHELL WITHOUT REINFORCEMENT

FIG. 2. UNEVENLY SPACED TUBES IN SHELL WITHOUT REINFORCEMENT

The majority of engineers are acquainted with the method of calculating the strength of riveted joints and that knowledge must be drawn upon to a certain extent when the reinforced tube sheet ligament is to be analyzed. We shall first refer to the tube sheet which has sufficient thickness to permit the reduction in strength resulting from cutting the tube holes, hence needs no reinforcement. This kind of tube sheet is quite common in water-tube boilers of the bent tube type and is shown in Figs. 1 and 2, both in plan and in cross section. Two methods of tube spacing are illustrated, although that detail differs more or less according to the taste of the manufacturer of the boiler. The reduction in strength is apparent from the longitudinal cross section "A-B" and can be determined mathematically from the relation:

$$E = N(P - d)\ t \times ts \times 100 \div (NP \times t \times ts)$$

in which E is the efficiency of the joint, N, the number of tube sheet ligaments in a unit section, P, the distance between tube hole centers, d, the diameter of the tube hole, t, the thickness of the tube sheet and ts, the tensile strength of the plate.

Passing to the consideration of the reinforced tube sheet boiler, we subject both the tube sheet and the reinforcement to the same analysis. The strap and riveting should about balance and be of equal or greater strength as compared to tube ligament in the tube sheet, although in practice considerable variation is met and as a result the structure may be excessively strong in some part and weak in another.

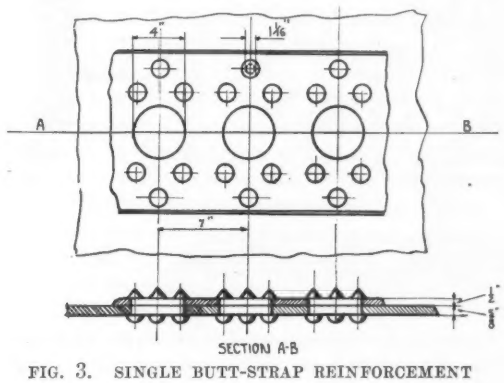


FIG. 3. SINGLE BUTT-STRAP REINFORCEMENT

Consider the layout shown in Fig. 3:

t, the thickness of the tube sheet.....½ in.
t', the thickness of reinforcing strip .....⅝ in.
ts, tensile strength .....55,000 lb.
Ss, shear strength .....44,000 lb.
d, diameter of tube hole .....4 in.
d', diameter of rivet hole .....1 1/16 in.
P, distance between tube centers.....7 in.
N, number of tube pitches considered.....1

The strength of the various elements is

Solid plate section...$N \times P \times t \times ts$ = 192,500 lb. (1)
Plate tube ligament..$N(P-d)t \times ts$ = 82,500 lb. (2)
Strap tube ligament..$N(P-d)t' \times ts$ = 103,125 lb. (3)
Rivets in shear....$N(3.14\ r^2)\ 44{,}000$ = 91,119 lb. (4)
Plate rivet ligament..$(P-d')\ t \times ts$ = 163,281 lb. (5)

Combining solutions

Numbers 2 and 3.....185,625 lb.
2 and 4.....173,619 lb.
3 and 4.....194,244 lb.
5.....163,281 lb., weakest

Efficiency = 100 × 163,281 ÷ 192,500 = 84 per cent.

From this solution it will be noted that the combined efficiency of the tube sheet ligament and reinforcing sheet ligament is 95 per cent of the strength of the tube sheet without holes while the net section of the plate along the line of rivet holes at 7-in. pitch is but 84 per cent. A thinner strap and smaller rivet might have been used to advantage.

Another design frequently encountered is shown in Fig. 4, which illustrates in plan as well as longitudinal and girthwise cross section a combination of double-butt-strapped seam and circulating tube connection in which the seam of the steel drum is formed by abutting together the ends of the shell plate along the line of circulating holes.

In such construction the strength of the inner strap and the strength of the outer strap combined, after the tube holes have been deducted, are the principal factors.

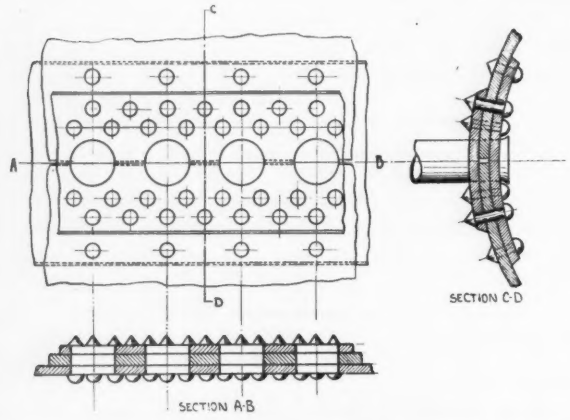


FIG. 4. DOUBLE BUTT-STRAPPED SEAM AND CIRCULATING TUBE CONNECTION ON SHELL

In the longitudinal section, "A-B" that part of both straps shown in section represents the material remaining after the tube holes have been cut. It is this section that takes the whole strain of the shell. The shell plates abut each other at this line (A-B) and, of course has no strength at that point. If the inner and outer straps are of the same thickness and strength, both will be double the strength of one and the calculation would be carried out just as we would for the inner strap in the preceding example; however, in such construction the riveting is somewhat different, as the outer strap must be calked for tightness, which could scarcely be done with rivets spaced 7 in. on a ½-in. sheet. For this reason the inner strap is somewhat wider than the outer strap and carries an additional row of rivets as will be seen on the girth-wise cross section, "C-D," Fig. 4. When determining the size of rivets necessary to support this seam, the usual practice for triple or quadruple riveted butt strap joints is as follows: Those rivets passing through the shell and both straps are considered as in double sheer, while the rivets in the outer row on each side of the tube section pass through the shell plate and inner strap only, and are in single sheer. There is no limit to the variations in the manner in which rivets may be arranged and each design must be analyzed in the manner indicated.

Chicago, Ill. J. P. MORRISON.

Condensate Return Lines

IN ANSWER to the question by G. S. in the March 1 issue, page 305, I should say that the installation of condensate returns seems to be practical with but one exception, and that is the location of the hot water tank supplying the condensate to the pump.

In order to handle hot water satisfactorily with a pump, a positive head must be supplied so that the pump will not have to suck the water at any time. The steam traps at the outlet of each drier coil will lift the condensation approximately 2 ft. for every pound steam pressure at the steam trap, therefore, if the steam pressure in the coils is in the neighborhood of 30 lb., the hot water tank may be placed 3 or 4 ft. above the pump and the traps will lift the condensation into the tank. A regulator may be installed in connection with the tank to operate the pump automatically so as to maintain a given water level in the tank at all times, otherwise the wear and damage to the pump at times when there was not sufficient water for the pump to handle would be expensive.

If the pump does not discharge direct into the boiler a lifting or pumping trap may be used with greater economy and less attention. The tank could also be eliminated by connecting the trap discharge line direct into the pumping trap.

Cleveland, Ohio. H. F. WOOD.

Remodeling Refrigerating Plant

IN ANSWER to the question submitted by C. J. R. on page 254 of the Feb. 15 issue, concerning certain points of design involved in remodeling his refrigeration system, I would say that it would probably be advisable to install a brine system in place of the present direct expansion system.

About 230 sq. ft. of brine-pipe surface should be used, equivalent to 530 ft. of 1¼-in. pipe 460 ft. of 1½-in. pipe or 370 ft. of 2-in. pipe. The old ammonia pipe could be used if it is in good condition; new pipe could be added if it is not of the required length. It should be blown clean with steam or hot water in order to remove oil from the inner surfaces.

It is not necessary to use a separate brine-cooler; the brine pump can take its suction from one end of the ice tank and the returning brine can enter the tank at the opposite end so as to keep the brine in motion.

The old 24-can tank is large enough to handle the load but the suggested addition of capacity to the tank will mean just so much more cold brine stored, which will be appreciated in case of an unexpected shut down for repairs. With the new equipment the total load due to the brine coils and the 44-can tank will amount to from 5 to 5½ T. of refrigeration. As the compressor is of 7-T. capacity it can just handle the load.

It is stated that the motor driving the compressor is of 20 hp. capacity. This is much larger than necessary; 10 to 12 hp. would be plenty. I would suggest that a larger pulley be placed on the motor so as to speed the compressor up to about 80 r.p.m. increasing the capacity to about 10 T. In this way the motor will be more efficient, the temperature can be rundown and the machine shut down part of the time. In this case the condenser must of course be large enough to take care of the added load.

For the greatest effectiveness the brine pipes should be in two coils, one on the ceiling and one on one of the walls or they can be placed one on each of the 15-ft. walls. The coils should be connected in parallel, each having a valve at its inlet and outlet.

Cork covering is probably the most efficient and easiest to take off for repairs, but there is also good hair felt covering on the market. Genuine wrought iron pipe is the best to use in the coils and the brine should be of calcium chloride since salt brine is liable to clog up the pipes.

For brine circulation a centrifugal pump will probably be best suited, one that will circulate about 5 g.p.m. should be about right.

Brooklyn, N. Y. E. MATZAN.

Secondary Air Supply

REPLYING TO H. C. R.'s question on secondary air supply in the Feb. 1 issue of Power Plant Engineering, page 203, I would like to offer the following which, I trust, may be of some benefit to him.

In the first place, much can be accomplished in keeping a stack from smoking by careful firing. By careful firing, I mean even spreading at each firing, keeping the fire as near a uniform depth as is possible and practical under the load conditions, keeping the fuel bed free from holes and attention to the draft regulation. The load condition is an important and sometimes deciding factor in smoke abatement.

If you have to force your furnace to meet the steam demands, you will be aggravating the condition causing smoke, to an extent where it would be practically impossible to keep the smoke down. Increased load means a heavier fire, and increasing the fuel bed thickness cuts down the available amount of air that can be used.

Before attempting a secondary air admission as outlined I would suggest that if you will avail yourself with a flue gas analyzer and draft gage you may do a lot toward finding out what makes your stack smoke (assuming you do not possess one).

Unless you blow your tubes regularly and thoroughly, you may expect smoke; if you have a filled in combustion chamber, you will be sure to get smoke with the kind of coal you are using, as there is not sufficient room to retard the expanding gases long enough to complete combustion. If you find you can boost your CO_2 up to 12 or 14 per cent, (12 per cent is a good average) you have little need to worry about smoke, unless you are in a congested area, and public complaint is against you.

Perhaps you are not using the coal you should for your furnace and without secondary air you could not entirely eliminate the smoke. Why not try a coal that is not quite so high in volatile matter? If you decide to try another kind of coal let the flue gas analyzer be your guide, and you will probably be able to find a coal that will fit your conditions without producing smoke. See that your dampers are open at the time of each firing. The vents on the furnace doors should be opened at the time of firing, and closed say from 2 to 5 min. after firing, depending on conditions. If opening the vents does not keep the smoke down, try cracking the fire doors.

If the stack still smokes, it will then be time for the consideration of secondary air supply but bear in mind that if you have succeeded in obtaining 12 to 14 per cent CO_2 in your flue gases, the best you can find in the smoke will not be above 2 per cent. Some method will have to be employed to induce cold air to enter your furnace and it will have to be heated just as if you opened a fire door.

Common practice is to take air in over the fire during each firing period and since the air admitting apparatus is usually automatic air is admitted for a pre-determined period after each firing until a great part of the volatile matter has been burned off.

The object in taking air over the fire rather than through the bridge wall is that more time is given for the gases and secondary air to mix, which is the important consideration when admitting extra air.

However, both methods are coal savers to the extent I have mentioned, provided you are obtaining the value of CO_2 I have given.

Worcester, Mass. LEROY BLAKE.

Pump Runs With Vacuum in First Stage

I HAVE a 300-g.p.m. three-stage centrifugal pump. Why is it, if the pump is brought up to full capacity, a vacuum is created in the first-stage casing but if the capacity is cut down about 25 per cent, then there is a pressure in the same stage? What causes this change? The water for the seal ring is taking from the second stage. L. B.

A. It is probable that the vacuum created in the first stage of your three-stage centrifugal pump when it is operating at full capacity is due to the inability of the suction line to provide for the full flow. Obviously, the quantity of flow passed any two given points in the pump must be the same or else there would not be continuity of flow. If the pump has a tendency to deliver more water than can be supplied through the suction line, then the pressure in various parts of the pump will so adjust itself as to decrease the delivery and increase the amount of suction. The difficulty could be overcome either by increasing the head on the suction or by increasing the size of the suction ports and piping.

The fact that pressure is built up in the first stage when the flow is restricted by throttling the discharge line further bears out these statements. By throttling the discharge, the quantity of flow is obviously reduced and under these conditions, the suction line has no difficulty in supplying all the water required.

Charging Ammonia System

IN THE April 15 issue on page 451 D. L. Fagnan says that there is danger of ammonia reversing its flow and returning to the empty drum from which it was drawn during charging.

I have charged ice machines of several different makes many times and never had this happen and do not see how it can occur. The pressure must become lower in the drum than in the low side of the system in order to flow backwards and as long as the machine is running this does not seem possible to me.

If the machine stopped for any reason during the charging process only that small amount which might, in some cases, return by gravity from the liquid line could run back; however, if this is possible will someone please explain how? I should dislike to think I was taking ammonia out of a drum and suddenly find it was filling up.

Westboro, Mass. W. W. WHITE.

POWER PLANT ENGINEERING

Trade Mark, Reg. U. S. Pat. Office

Published by the Technical Publishing Co.

537 South Dearborn Street, Chicago.

Entered as second class matter May 1, 1908, at the Post Office at Chicago, Illinois, under the act of March 3, 1879. Issued the 1st and 15th of each month. Established over 27 yr.

Subscription price $2.00 a year in the United States and all its possessions. Canada $2.75 a year. All foreign countries $3.50 a year.

Copies of current issue, 15 cents; of back issues, 25 cents.

Copyright, 1924, by Technical Publishing Co.

Member, Associated Business Papers.

Member, Audit Bureau of Circulations.

New York Office, 150 Nassau St.

Circulation of this issue, 23,850

CONTENTS

Boilers at Cleveland Rate 3060 Hp. Illustrated....517

Requirements for Burning Pulverized Coal Efficiently. By S. C. Martin. Illustrated....525

Efficiency in Oil Burning Installations. By F. A. Rothwell. Illustrated....526

Operation of Radiant Heat Superheaters. Illustrated....528

Tendencies in Surface Condenser Practice. Illustrated....530

Adapting Evaporators to Heat Balance—I. By Ernest H. Chapin. Illustrated....534

Chart Gives Contents of Tank. By W. F. Schaphorst. Illustrated....536

Operating Features at Delaware. Illustrated....537

Load Dispatching System of P. G. & L. Co. By C. W. Geiger. Illustrated....543

Operation of Steam Jet Ash Conveyors....545

Pointers on the Care of Electrical Equipment. Illustrated..546

Hudson Ave. Plant in Operation. Illustrated....549

Motor Standardization of the Electric Power Club. Illustrated....553

The Inquiring Engineer....554

Notes on Centrifugal Pump Specifications. By John D. Morgan. Illustrated....555

Negotiating the Purchase of Stokers. By H. N. Scofield....559

Methods for Applying Lubricants. Illustrated....560

Letters Direct from the Plant: Novel Feed Water Heater. Heavy Firing of Steam Boiler Furnaces. Repair for Hydraulic Pressure Pump. Larger Exhaust Pipe Cures Oil in Ice Problem. Doing Away with Licensed Firemen and Engineers. Jacking Up an Engine Shaft. Unusual Engine Foundation. Rotary Pump Adopted for Hard Service. Isolated vs. Central Power Plants. Illustrated..563

Problems in Operating Power Equipment: Ligament Efficiency. Condensate Return Lines. Remodeling Refrigerating Plant. Secondary Air Supply. Pump Runs with Vacuum in First Stage. Charging Ammonia System. Illustrated....567

Editorial: Superpower Must Come Through Natural Growth. Utilizing Radiant Heat. Summer-Time Overhauling....570

Off Duty....571

Sixteen Advances in Hydroelectric Practice. Illustrated....572

Economic Status of the Oil Engine....573

New Design of Craig Furnace Pressure Regulator. Illustrated....574

Sliding Valve Is Feature of New Soot Cleaner. Illustrated..575

H. M. Byllesby Dies Suddenly. Illustrated....576

Death Claims Alfred Cotton....577

News Notes....577

Books and Catalogs....578

Superpower Must Come Through Natural Growth

In the consideration of schemes for the promotion of superpower, the radical advocates of interconnected systems seem to have assumed two premises which have no bearing on the problems of this development. First, that a superpower system must involve long distances and, second, that the interconnection of systems can be forced by pressure, either moral or legislative.

When the superpower survey was made by governmental agencies in 1920 the work was confined mainly to that section of the East where the power density of the country is maximum. Since that date no definite progress has been made toward tying the systems from Washington to Boston together. Moreover it is doubtful if any further progress will be made for a number of years.

This is quite a logical outcome when analyzed from the angle of power density. The systems around Philadelphia, in New Jersey, New York and Boston are in reality each of superpower magnitude; hence the economic gains from interconnection are not sufficient to warrant the burdens of interconnected operation.

When it is considered that the stations operating in Manhattan and Brooklyn are probably the equal in capacity to the total of those feeding into the entire interconnected network in the South, an inkling of reason may be discovered as to why the Eastern companies have not looked favorably on system interconnection.

After all the arguments are in, the ultimate decision for superpower operation must rest on economic gain to the individual companies, either through greater reliability afforded to consumers, reduction in reserve capacity or lower operating costs.

Forced development will not bring this about. It will be a matter of slow growth and it will come about when conditions warrant the step. This is shown by the recent developments in the Eastern coal fields where the power density is not so great and where the companies have worked the problem out on a basis of engineering and financial economics.

A national superpower system, if one is ever evolved, must come as a matter of economic necessity to the systems involved.

Utilizing Radiant Heat

In designing a boiler furnace one of the first essentials is to consider the way in which the heat generated in the furnace is to be utilized. Modern practice in the power industry is tending toward higher steam pressures and temperatures. To put in practice what theoretical calculations have shown to be most economical, many changes in the design of furnaces have been necessary.

To burn the fuel completely is the duty of the furnace; to utilize that heat in the generation of steam is the function of the boiler. The more of the heat that can be used in this way, the higher will be the efficiency. It is, therefore, essential to distribute the heat absorbing surfaces so as to make best use of the heat generated.

In the transfer of heat from one gas or liquid to another, the counterflow principle has given the highest efficiency. In the generation of steam this principle has been applicable only to a limited extent. Several types of water-tube boilers used in connection with economizers come the nearest to the counterflow principle that has

been developed; the temperature difference between the water in the tubes and the gases in the furnace, however, is excessive, amounting in many cases to 2000 deg. F.

One of the big problems in furnace design has been to proportion the walls and arrange the heating surfaces so as to maintain a temperature which will insure complete combustion yet will not melt down the furnace lining or cause clinkers. When anthracite and low volatile eastern coals were the common fuels in power plants, combustion space requirements were moderate and the boiler was placed down near the fuel bed or, as in the case of internally fired boilers, the heating surface completely surrounded the burning fuel. This kept the furnace temperature low but such an arrangement also keeps down the possible rate of combustion so that with high volatile coals combustion of the gases is incomplete.

Bottling the heat by means of dutch ovens, arches, roof tiling and wing walls has been resorted to for securing complete combustion but, at the high combustion rates now in general use, this results in melting down the furnace linings and causes clinkers.

Where high rates of combustion are employed, the tendency now is to build large furnaces and keep the temperature down by exposing more heating surface to the radiant heat of the furnace. This may be accomplished by rearranging the boiler baffling, providing water backs for the front of the bridge wall, supplying water screens to prevent fusion of ash in powdered fuel furnaces and the most recent arrangement is by lining one or more of the furnace walls with steam superheating surface. This last arrangement extends the use of the counterflow principle of heat exchange in boiler practice and has worked out very satisfactorily in a number of plants. Steam temperatures as high as are likely to be employed for power purposes can be maintained and space occupied is that which would otherwise be required for furnace lining.

Summer-Time Overhauling

With the coming of warmer days our thoughts are inclined to turn to things other than those concerned with the power plant. Some of us will be found blowing last winter's dust off the old bag of golf clubs. Others resurrect the fishing pole from its hiding place in the attic and put it in shape for active service. The suburban dweller gets out his implements of the soil and prepares to spend much of his spare time in his garden.

To the power plant engineer, the coming of summer suggests an opportune time to overhaul his equipment. During the winter months when the load is heavy, and when all equipment must be kept operating, it is often impossible to do any overhauling. As the days become longer, however, the load on many industrial plants drops off somewhat and the wise engineer will take advantage of the opportunity given him to put his equipment in first class shape.

This should be done systematically. It is a good plan to make a list of all equipment that will need overhauling. From this list, cards are made out, one for each machine, on which are listed the details of work to be done on the machine. These cards are given to the operators in the plant, who will do the actual work. When the cards are returned to the chief engineer or the power superintendent, they should contain a record of all work done, and if for any reason the instructions on the card could not be carried out, the reasons should be stated.

In this connection, the "overhaul schedules" used by the Philadelphia Electric Company at the Delaware Station, will be of interest. These schedules which are shown in this issue, in an article on the operating features of this plant, are used in the regular maintenance of the station, and while they are of a more elaborate nature than those which will be used in the small plant, the general arrangement is the same.

Off Duty

Making the lion and the lamb lie down together has long been a favorite example of the almost unattainable. Also the harmonizing of peace and war. No, this is not a pacifist or a militarist argument but look what the engineer is doing. He is taking a section of a Big Bertha and mounting it over a part of the transept of one of the cathedrals which the big gun demolished and Lo! You have a modern super-pressure boiler, burning pulverized coal and furnishing power to knit socks for the baby.

Here's what they are doing for steam drums for the 1200-lb. boilers. We have been worrying along trying to get a joint that would be as near as possible the same strength as the plate, with butt plates and double riveting, then triple riveting, then quadruple riveting. We rolled the plates and sheared them and drilled them and reamed them. It was getting to be a lot of a job, too, with plates first 1 in. thick, then as pressures crept higher, 2 in. thick. Isn't that a clumsy thing even to think about? A quadruple-riveted, butt-plate joint in a 2-in. plate? Well, the designers have borrowed a leaf from the gun makers and decided that "there ain't goin' to be no joints."

Take a 78-in. octagon steel billet, weighing 262,000 lb., upset it to 96 in. diameter; then drive a hollow punch through it endwise and take out a 23-in. core. Then you stick it in rolls and expand it to 50 in. inside diameter, draw it down on a mandrel to 45 in. inside diameter and 58½ in. outside diameter, anneal it, test it, machine it inside and out and swage in the ends to form the manholes. That's the steam drum for a 1200-lb. boiler.

But where does the church come in? Did you ever stand in a cathedral and look up at the vaulted roof? That's where they got the pattern for the furnaces for burning pulverized fuel. Fifty feet clear from the ash dump to the steam drum. Step outside and take a look at a point 50 ft. in the air. Then consider that the ground area of the furnace is 45 by 27 ft. You could build a 10-room house inside one of those furnaces and have room for a garage besides. If they stop using the furnaces, put in a few floors and partitions and you have a building which will rent for 20 or so modern kitchenette apartments.

Now allow for a track below for the ash handling cars and room above for economizers, piping and breechings. Then allow for coal bunkers, coal handlings, water treating, steam and water piping, blowers, pumps and control apparatus and look at the building you get. Cleared of equipment and floors and with a little ornamentation outside and in, it would be as impressive in grandeur as one could wish.

If you haven't seen one of these super plants, take the first opportunity to do so. It will be a good use of off duty time and you'll get a new idea of how far it is found practical to go in the chase of the elusive little heat unit.

Sixteen Advances in Hydroelectric Practice

MEETING OF CHICAGO'S WESTERN SOCIETY OF ENGINEERS COVERS SIGNIFICANT DEVELOPMENTS IN HYDROELECTRIC FIELD

IN COMMENTING on the most significant advances in hydroelectric engineering, in an address before the Western Society of Engineers on April 21, L. F. Harza,

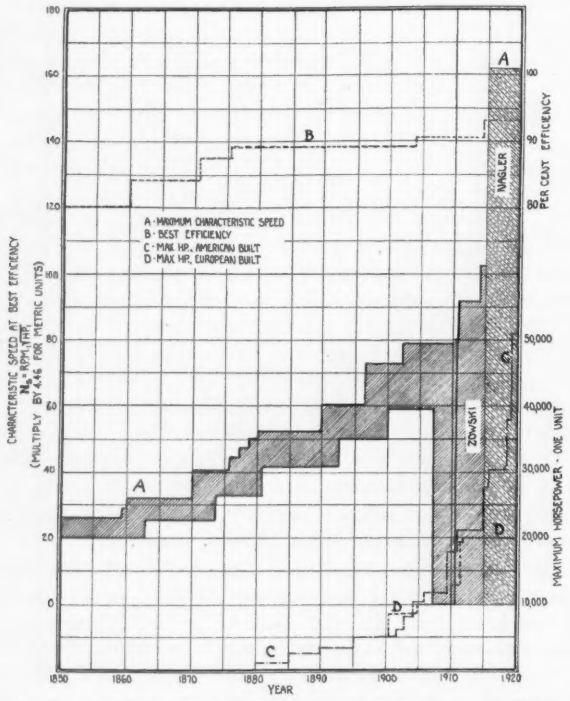


FIG. 1. GRAPHICAL REPRESENTATION OF THE DEVELOPMENT OF HYDRAULIC TURBINE

consulting hydroelectric engineer of Chicago, stated that these from the year 1900 might be listed as follows:

1. Change from horizontal to vertical units for practically all Francis turbine installations of low or high head following the development of successful step bearings.

2. An increase in size of Francis turbine units from a maximum of 5000 hp. in 1900 to present of 70,000 hp. and impulse turbines up to 35,000 hp.

3. Improvement in efficiency guarantees from about 78 to 80 per cent in 1900 to as high as 90 per cent at the present time.

4. Change from multiple runner to single runner units.

5. Increase in specific speed from about 80 to 170 or more than double the speed that was available at the beginning of the period.

6. Introduction of the propellor type of runner, a distinctly new type of runner of much higher speed than the Francis runner.

7. Improvement of draft tubes from the old curved elbow of about zero efficiency to a modern tube with efficiencies of about 80 per cent under straight line flow and capable of regaining also a considerable proportion of the whirl energy; this improvement having resulted largely from the introduction of the symmetrical draft tube.

8. Increase in the head limitations of the Francis turbine from around 400 ft. to 857 ft. thus encroaching upon the high head field previously monopolized by the impulse turbine.

9. Recent announcement of a new type of impulse turbine which exceeds the Francis turbine in speed and may regain some of the ground lost by the impulse turbine in the past.

10. Substitution of tunnels for flumes and ditches in high head developments.

11. Introduction of the hydraulically balanced valve for pipe lines.

12. Rubber seal rings at the leakage clearances.

13. Introduction of the back water suppressor.

14. Use of outdoor high tension substations thus clearing the power station of this apparatus.

15. Automatically operated hydroelectric stations capable of starting, synchronizing and stopping automatically under nearly any requirement of service or operating hazard.

16. Increase in transmission line voltages to as high as 220,000 v.

Up until about 1911, Mr. Harza pointed out that vertical units were not in favor because the bearings which were of the ball, roller or floated oil pressure type were not successful. With the advent of the Kingsbury thrust bearing and others of this general type, the vertical units made rapid progress. Soon after the change from horizontal to vertical units came the change from multi-runner to single runner units. According to Mr. Harza the vertical unit met resistance because the generator was more expensive than the horizontal and the single runner met resistance because it required slower speed and therefore a more expensive generator. Recent examples of large single runner vertical units are three 37,500 hp. units of the Niagara Falls Power Co. for 215 ft. head installed in 1918-1919, the 55,000 hp. units at 305 ft. head of the Ontario Hydroelectric Corp. first installed in 1920 and three new units, the first one of which was started last December, of 70,000 hp. at 215 ft. head, for the Niagara Falls Power Co.

In comparing European practice with American, Mr. Harza stated that European practice still adheres largely to the old type of multiple runner, horizontal, open flume, unit which is entirely obsolete in this country.

One reason cited for the improvement for the vertical type unit has been the increase in specific speed of the Francis turbine and the development of the propellor type wheel.

Improvement in Draft Tubes

Mr. Harza asserted that one of the greatest single factors contributing to the improvement in hydraulic practice has been the draft tube. The first radical departure in draft tubes was made by W. M. White, of the Allis-Chalmers Co., in 1917 when the "hydraucone" draft tube was brought out. This consisted of a conical expanding tube for a distance, then flaring out rapidly in the form of a bell, discharging water around the entire circumference.

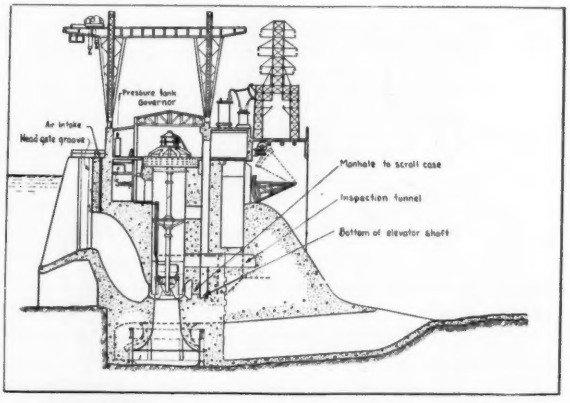


FIG. 2. TAIL WATER SUPPRESSOR MAINTAINS THE EFFECTIVE HEAD DURING FLOOD STAGES

This type recovered a greater part of the kinetic energy of the turbine discharge. Following the hydraucone, L. F. Mood, of the I. P. Morris Co., added a center cone inside of the White hydraucone and this center cone has grown in height and importance until the latest installation and best practice now calls for this cone to extend entirely up to the hub of the turbine runner.

The new type of impulse turbine referred to by Mr. Harza is one in which the jets impinge laterally against the buckets, whereas in the former types the jets impinge tangentially. As a result of the new design, specific speeds as high as 250 have been obtained with models. This is far above the highest specific speed of the Francis turbine instead of below, as has always been the handicap of the Francis turbine. None of the new type have as yet been applied commercially.

Another development of considerable interest cited by Mr. Harza, is that of the back water suppressor by O. G. Thurlow, chief engineer of the Alabama Power Co., which has already been applied to the Mitchell Dam on the Coosa River. Low head power stations are almost universally crippled in capacity during floods because of the fact that the tail water rises during flood whereas the head water either rises at a smaller rate or is kept constant by opening of flood control gates. This results in a reduction of head during flood stages.

Mr. Thurlow has solved this problem by building the power units in the form of deep wheel pits of small diameter constructed in the deep water up stream from the spillway of the dam leading the draft tube discharge under the spillway and leading the flood waters around these isolated turbine pits to the spillway down stream as shown in Fig. 2. The large volume of water discharges over the spillway with sufficient momentum to push the high tail water down the river away from the toe of the dam, allowing the draft tube to discharge into this reduced tail water elevation, thereby maintaining the full effective head of the station even under maximum floods.

Although the Mitchell dam has been in operation for only a few months and has not yet passed through an important flood stage of operation, the back water structure has functioned entirely according to the theoretical calculations and experiments which were previously made on small models.

Economical Status of the Oil Engine

Dr. Lucke Analyzes Power Situation With Respect to Place of the Oil Engine

"RELATION of the Oil Engine to the Economic Production of Power" was the subject of a paper presented by Dr. Charles E. Lucke of Columbia University at a meeting of the Metropolitan Section of the A. S. M. E. on April 22.

Starting with the prime factors of suitability and cost for setting up a basis of competitive value, it was shown that where these are both unequal the problem is most complicated. At present, according to Dr. Lucke, three systems may be considered: (1) Superpower, relying for economies on small number of large generating stations; (2) Higher economies in steam turbine stations; and (3) Higher economies in oil engine stations. The item of suitability is easily judged and often obvious but that of cost is less readily handled. For handling the latter, the common factor of cost per million B.t.u. was suggested as most available and a slide was presented showing conversion from cents per kw.-hr. to cents per million B.t.u.

Three increments cited by Dr. Lucke to account for the reduction in commercial efficiency of power production were: (1) energy loss in process, (2) investment in equipment and (3) operating disbursements. In reducing these to mechanical terms, it was shown that if A is the cost per mill. B.t.u. input energy; B, the cost cost per mill. B.t.u. output energy; E, process efficiency; E_c, commercial efficiency; O, operating disbursement increment; and I, investment increment; then the inefficiency increment $=$

$$\frac{1-E}{E}A.$$

Output energy cost was shown by Dr. Lucke to be represented by the equation

$$B = A + \frac{1-E}{E}A + O + I.$$

and the commercial efficiency by the equation

$$E_c = \frac{A}{B} = \frac{A}{\frac{A}{E} + O + I} = \frac{E}{1 + E\frac{O+I}{A}}$$

In dealing with this problem, the cost of transporting primary energy in the form of natural products from its source to the point of utilization must be included, as well as the cost of transmission of electrical energy from the point of generation to the customer.

Super Power Will Not Put Small Plant Out of Business

By means of exhaustive analysis with tables and charts, it was shown that the superpower station cannot expect to put the isolated plant out of the running but that a zone may confidently be expected to exist, in which the highly developed oil engine will be able to compete with purchased power on terms of supremacy. While the indications are that this zone will be confined to the smaller plants, rising prices of coal may extend its limits.

Discussion of this paper consisted mainly in answering questions from the floor. The author said that although the curves presented were based on 40 per cent use of capacity, the figures in the paper were arranged to enable easy computation for other conditions. As to stability of supply, relative to coal, none can tell; but repeated predictions of imminent oil shortage have proved unfounded. Processing of coal is a present tendency and although the Diesel engine of today cannot burn tar oil, the design will be changed when necessity arises.

On the subject of central station competition, Dr. Lucke seemed to think that the Diesel engine might be used as a pathfinder by the central stations for opening new fields, caring for the smaller load with a Diesel installation until growing demand justified its removal to a less developed district and substitution of a larger steam station or substation.

As to the gas producer engine, the higher first cost and higher fuel cost have eliminated it from competition in most parts of this country. This is not so in Europe; and the reason appears from the coal cost figured in hours of common labor. In the United States, this is 10 hr.; in France, 50 hr.

New Design of Craig Furnace Pressure Regulator

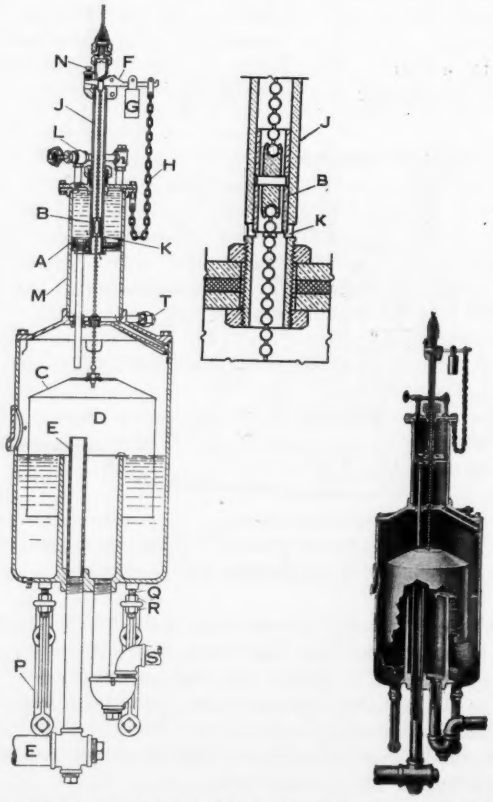
SEVERAL changes have been made in the design of the Craig furnace pressure regulator according to recent announcements of the A. W. Cash Co., of Decatur, Ill. The changes have to do mainly with the method of controlling the admission of water to the hydraulic cylinder, which supplies the motive power for the actuation of the damper.

This regulator operates in accordance with changes in the over-fire draft pressure and makes use of a gasometer principle to change the pressure variations into a movement which will actuate the pilot valve.

Referring to the sectional views shown in accompanying illustrations, the action of the regulator is as follows: Needle valve (L) supplies water to the hydraulically operated power piston (A) which closes the damper. The power piston is controlled by a sleeve valve (B), and this valve in turn is operated by a gasometer or bell float (C) which responds to the slightest change in overfire draft. The damper is opened by means of a counterweight.

A bell float or gasometer (C) is provided with a water seal so as to form draft chamber (D). This draft chamber communicates by draft pipe (E) with the over-fire chamber of the boiler furnace. The gasometer is suspended by a chain from a beam (F) which is carried on knife edges. The weight of the gasometer is counter-balanced by a draft weight (G). It is obvious that the suspended weight of the gasometer varies directly as the volume of water it displaces. Chain (H) compensates for this variation, for its effective weight varies exactly opposite to the changing weight of water displaced by the gasometer.

As the piston rod (J) is hollow, it forms a cylinder for sleeve valve (B). At the bottom of piston rod (J), close to the power piston (A), are four ports (K) which relieve the pressure on power piston (A).



POWER PISTON IS CONTROLLED BY A SLEEVE VALVE WHICH IN TURN IS OPERATED BY A GASOMETER

Sleeve valve (B) is mounted on the gasometer chain so that the sleeve valve and the gasometer move as a unit and in moving, the sleeve valve (B) varies the opening of the four ports (K) thereby controlling the water pressure in the power cylinder (M), hence the movement of power piston (A).

How the Regulator Operates

Assume that the Craig regulator is installed and adjusted to maintain 0.05 in. over-fire draft and under the prevailing furnace conditions the damper is half open. Everything is momentarily in balance and there is no perceptible movement of the regulator. Valve ports (K) are open sufficient to pass the small amount of water being admitted by needle valve (L), hence the power piston (A) is stationary.

Then something happens which tends to increase overfire pressure. It may be one of many things. Suppose

it is a sudden increase in load. In this case the forced draft fan speeds up, forcing more air through the fuel bed which would increase the over-fire pressure, were not the damper instantly opened wider. With the beginning of the slightest increase in over fire pressure, the gasometer (C) and the sleeve valve (B) rise in unison, increasing the opening of ports (K) and relieving water from power cylinder (M) more rapidly than it is admitted through needle valve (L). Thus the pressure on power piston (A) is reduced, allowing the damper counter-weight to increase the opening of the damper.

In this operation the power piston, sleeve valve, gasometer, draft weight and compensating chain, rise as a unit. When they have risen sufficiently to secure the new damper position, the balance of gasometer (C) and draft weight (G) is restored and the upward movement of power piston (A) has reduced the opening of ports (K) enough to stop further movement.

Sliding Valve Is Feature of New Soot Cleaner

IN A NEW type of soot blower head which has recently been developed a sliding valve is used, which does not require the use of a stuffing box or a sliding stem and no extra packing gland is necessary. As will be noted from the accompanying illustrations, the valve in the wide open position is clear of the steam passage.

In this design the steam chest or valve body is made either of iron or steel, to suit the pressure and temperature under which it is to operate. At the inner side of this valve body is a stuffing-box through which the element extension passes, and this stuffing-box is kept steam tight by means of packing of the highest grade. At the outer side of this valve body a cover is bolted, as shown in Fig. 1, the joint being maintained steam tight by means of a metallic gasket. The steam connection is made at the

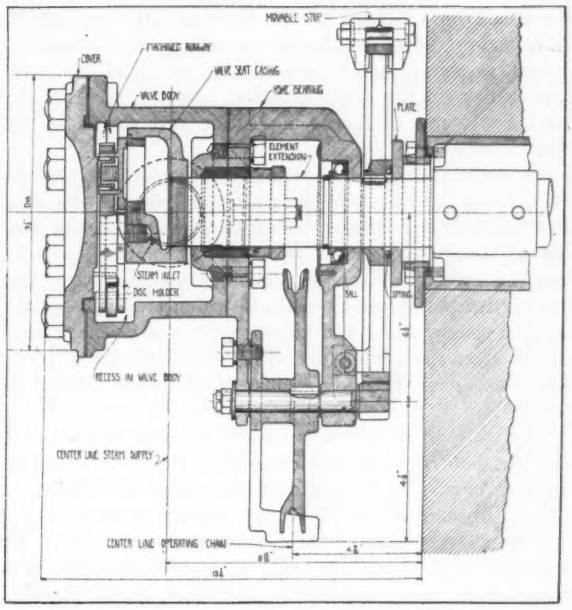


FIG. 1. VALVE ACTUATING MECHANISM CONSISTS OF BUT TWO PARTS, THE VALVE DISC AND THE STIRRUP PIECE WHICH ACTUATES THE VALVE DISC

inlet. Within this head the valve parts are housed. The valve seat casting is attached to the element extension, this connection being screwed, keyed and peened over. The valve seat casting is made of either iron or steel, to suit the temperature conditions, and in this casting a renewable monel metal seat is assembled.

The valve disc floats within the stirrup piece or disc holder and is held by spring contact against the seat face. The spring is not for the purpose of closing the valve, but simply to form a light contact, the pressure of

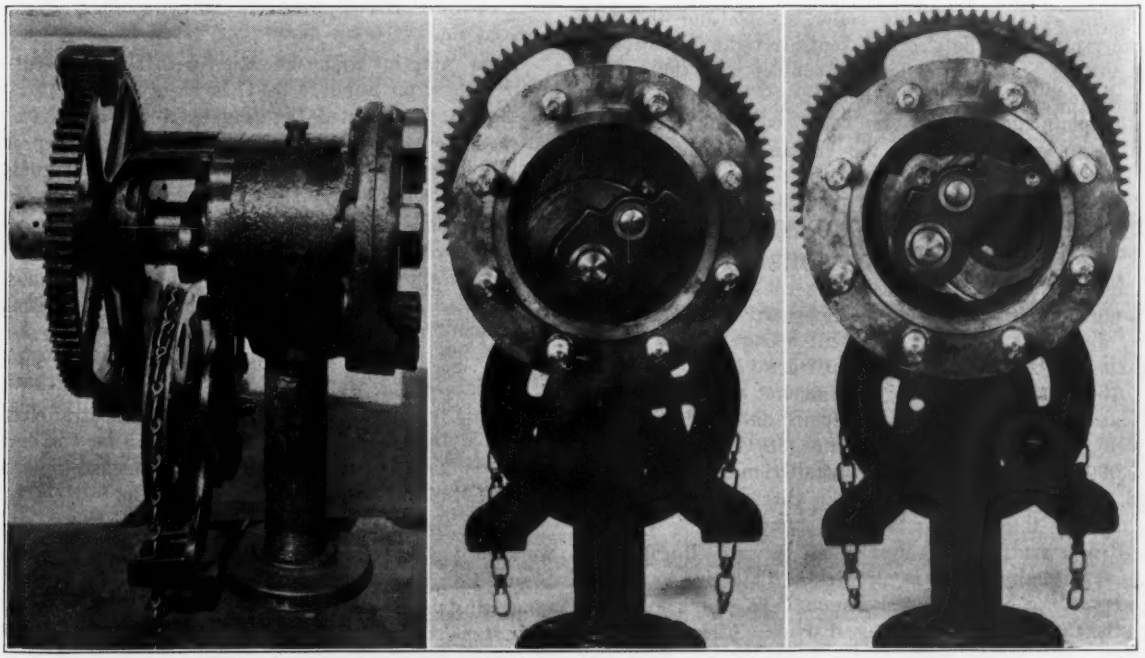


FIG. 2. SOOT BLOWER HEAD AND VIEWS SHOWING VALVE IN CLOSED AND OPEN POSITION

the steam on the back of the disc actually keeping the valve tight. Valve disc holder or stirrup piece rotates on a stud, as shown, and is actuated by means of the extension, which, in the closed position, enters a recess on the valve body, and in the open position just clears the machined runway.

From Fig. 1. it will be noted that the operating mechanism is carried by a yoke bearing, this yoke bearing being attached solidly to the valve body. The outer board bearing of the yoke forms a retaining recess for the radial and end thrust ball bearings. The extension of yoke bearing carries the operating shaft to which is attached either a chain sheave wheel and chain guide or a ratchet operating mechanism. This operating shaft carries a pinion which engaged with a drive gear keyed to the element extension.

Starting with the valve closed, the first movement of the element in a counter-clock-wise direction opens the valve. The valve is fully opened when the element is rotated through an arc of 30 deg. and the element may be continuously rotated in this direction and reversed, with the valve fully opened, through a range of 345 deg. This means that almost a complete revolution may be made in a counter-clock-wise direction, with the valve fully open, and then reversed and rotated through almost a full revolution,—with the valve fully open, before the point is reached where the valve automatically closes during the last 30 deg. of arc rotation of the element.

A stop is located within the valve body, which causes the closing of the valve at the end of the cycle. Supplementing the stop within the body are two external stops, one stop being a part of the drive gear wheel, the other, attached to the drive gear wheel, being movable to such a point as may be required to limit the forward rotation of the element through any predetermined arc of revolution, before reversing to complete the cycle of operations and to close the valve.

For the expansion sleeve a casting of rectangular section is used, in which clearance is allowed to accommodate the expansion of the boiler setting and the soot cleaner piping. The sleeve is kept air tight by means of the surfaced plate being held in contact with the end of the sleeve by the pressure of the spring. The inner surface of this plate and the sleeve are machined. This soot blower unit has been developed by the Vulcan Soot Cleaner Co., of Du Bois, Pa.

Southern Colorado Power Co. Plans $400,000 of New Construction

In order to accommodate the constantly increasing demand for electric power, the Southern Colorado Power Co., during the present year will spend a total of approximately $400,000 for new construction.

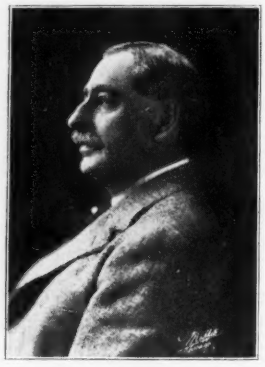
About $100,000 of the total amount will be used for extensions, improvements and repairs on the distributing system, which covers five counties of Colorado. About $85,000 will be used for the installation of new boilers and other improvements at Canon City and $80,000 will be used by the street railway department.

Reconstruction of power lines between Pueblo and Stone City already is in progress. This line furnishes power to the Skagway and Canon City plants and also to the Cripple Creek mining district. Changes in the system also will be made at La Junta, Rocky Ford and Sugar City.

H. M. Byllesby Dies Suddenly

Heart disease, with which he had been afflicted for years, on May 1 claimed H. M. Byllesby, president of H. M. Byllesby & Co. Mr. Byllesby was 65 yr. old. He had been in a serious condition for about eight months and had returned to Chicago, only two weeks previously, from California where he had spent the winter on account of the state of his health.

Mr. Byllesby served during the war, despite his age of 60 yr., as general purchasing agent for the A. E. F. In this capacity he was stationed at London. When he was discharged in 1918, he was awarded the distinguished service order by the British government. As a member of the American Society of Mechanical Engineers and a fellow in the American Institute of Electrical Engineers, he had always taken an active interest in engineering progress. In his social activities, he was a member of many clubs including the Union League and University clubs in Chicago.



Next to the fact that Mr. Byllesby was born in Pittsburgh, Pa., in 1859, the most important item of interest is that he was the son of a clergyman but failed to fulfill the time-worn expectation for a minister's son. His education was obtained at Western University of Pennsylvania, after which, until 1877, he took a course in mechanical engineering at Lehigh University. Not waiting to graduate, he went to work in the laboratory of a dynamo and electric machine shop. Here the practical experience he had gained by working during his vacation for 12 yr. stood him in good stead, and before long he went into the drafting room of the Corliss Engine and Mill Machinery Plant at Chester, Pa.

Then came his first connection with the electrical industry when, on June 1, 1881, he went to work for the Edison Co. for Isolated Lighting in New York City. A few months in the drawing room there brought a promotion, and he went to the Pearl Street Station of the original Edison Electric Illuminating Co., of New York.

Under the direction of the chief engineer and his assistant, Mr. Byllesby made all of the drawings for the structures, cranes, location of boilers, engines and switchboards of this plant, which was the first steam operated central power plant in the United States.

This work demonstrated his ability, and with an eye to the future, Mr. Byllesby accepted an opportunity to go to Canada to supervise the manufacture of Central electric devices, dynamos, etc. From 1884 to 1885 he was on the engineering staff of the Edison Co., but resigned to become Eastern Manager for Robert Wetherill & Co.

About this time Mr. Byllesby became interested in the work of George Westinghouse, of the Union Switch & Signal Co., who was venturing out on his own capital in some electric lighting project. At Mr. Westinghouse's request, he became associated in these ventures, and soon afterward the Westinghouse Electric Co. was formed, with Mr. Byllesby as its vice-president and general manager.

European fields loomed big on the horizon, and for two years, from 1889 to 1891, Mr. Byllesby spent most of his time abroad, representing the Westinghouse Co. Then suddenly, because of a difference of opinion with Mr. Westinghouse on financial affairs of the company, he resigned to become connected with the Thomson-Houston Co., which connection he maintained until it was absorbed by the General Electric Co.

Then there came to him the vision of generating current on a big scale by harnessing the swift running rivers of the Northwest. One of the first large pieces of construction work which he undertook successfully along this line was the building and financing of the original water power plant on the Willamette River at Oregon City. From 1894 to 1898, he explored Montana's waterways and constructed two hydro-electric projects and formulated plans which led eventually to the development of the Montana Power Co.

On Jan. 1, 1902, he organized the engineering firm of H. M. Byllesby & Co., of which he was president. At the outset, the activities of the concern were almost entirely engineering; but under Mr. Byllesby's able hand, the company expanded rapidly and shortly won distinction as one of the largest financing, designing, constructing and managing organizations in the electric light and power, gas and street railway fields.

Death Claims Alfred Cotton

ALFRED COTTON, chief research engineer of the Heine Boiler Co., who died at his home in St. Louis on April 17, 1924, was born in Southport, England, Nov. 30, 1871. While serving an apprenticeship from 1885 to 1892 in marine engineering, he received his technical education through university-extension courses and by private tuition. He was then engaged by Thomas Henderson of Liverpool, for whom he worked in designing mechanical stokers and grates until 1894, when he entered the Port Sunlight Soap Works of Lever Brothers, Ltd., as engineering assistant to the works manager. Here he designed one of the first, if not the first, double-stage centrifugal pumps, which operated with fairly high efficiency and entire satisfaction.

In 1898 Mr. Cotton became assistant chief engineer for Meldrum Brothers, Ltd., working on the design and adaptation of mechanical stokers and forced draft, and collaborating in the development of destructors for generating steam from municipal refuse. He came to America in 1903 and developed the Cotton furnace, which embodied a high-efficiency system of steam-jet forced draft. He manufactured and installed these furnaces and allied apparatus until the war, when he entered the employ of Colt's Patent Fire Arms Manufacturing Co., designing jigs, fixtures and tools for the production of the Browning machine gun. In 1918 he became chief engineer in the combustion department of the Sterling Blower Co.

Mr. Cotton came to St. Louis about 5 yr. ago as research engineer of the Heine Boiler Co. Many of their developments have been due to his ingenuity and broad knowledge of engineering principles. He was of a very inventive turn of mind and had many ingenious and original ideas, to cover which a number of patents have been issued, others applied for, and still more on which applications have yet to be made.

News Notes

H. H. VALIQUET, for the past 18 yr. chief engineer of the B. F. Sturtevant Co. (Chicago Division) will join the organization of The Kirk & Blum Mfg. Co., Cincinnati, Ohio, as chief engineer.

R. B. WILLIAMSON, electrical engineer-in-charge of alternating current design for the Allis-Chalmers Mfg. Co., sailed April 26 for a two months' trip to the British Isles and the Continent. During his trip Mr. Williamson will inspect European engineering developments and will attend the British Empire Exposition at Wembly.

PROFESSOR ELIHU THOMSON, one of the founders of the General Electric Co., sailed April 26, for a 3 mo. tour of European countries. While abroad, he will receive the Lord Kelvin gold medal, which was recently awarded to him. The presentation will be made early in June at London, England. This award, made through joint action of British and American engineering societies, occurs every 3 yr. and is a mark of distinction for excellence in research work in engineering. Professor Thomson is the first American to receive the honor.

DR. A. S. NICHOLS of the Nela Research laboratory, Cleveland, died suddenly on April 29, while reading a paper to the American Academy of Sciences. Dr. Nichols had acquired world-wide fame because of his researches on light pressures and because of his radiometer. The academy stopped all ceremonies on account of the death. Before going to the Nela laboratory he was president of Dartmouth college, and for a time was head of the Massachusetts Institute of Technology. He was born in Leavenworth, Kan., in 1869.

NATIONAL REGULATOR CO. announces the removal of its general offices and manufacturing plant to the company's new building, 2301 to 2311 Knox Ave., Chicago.

BRISTOL CO., Waterbury, Conn., has opened up a repair plant 3617 South Ashland Avenue, Chicago. Most of the plant will be devoted to repairing and recalibrating Bristol instruments sold and used in the Chicago territory, but some will be used for stocking made-up instruments for quick deliveries. The present salesroom and offices of the Bristol Company will be maintained in the Monadnock Building.

H. M. BYLLESBY & CO. announce the appointment of H. W. Fuller as chief engineer of the Byllesby Engineering and Management Corporation, succeeding Francis C. Shenehon, resigned. Mr. Fuller has been connected with the Byllesby organization and utility companies under its direction in various capacities since 1912, and for a number of years preceding the present appointment, occupied the position of vice president in charge of operation of the Northern States Power Co. Mr. Shenehon is to reopen his offices in Minneapolis as a consulting hydraulic engineer.

ILLINOIS POWER AND LIGHT CORPORATION has acquired the property of the Central Illinois Electric Co. The properties acquired furnish service in the Illinois towns of Buffalo, Lanesville, Mechanicsburg, Illiopolis, Niantic and Harristown. The properties are placed under the supervision and operation of the Decatur Division of the Illinois Power and Light Corporation, of which M. L. Harry,

Decatur, Ill., is general manager. The property of the Western Illinois Utilities Co., which renders electric service in the Illinois towns of La Harpe, Blandinsville and Stronghurst, has also been acquired.

Books and Catalogs

A TREATISE ON ENGINE BALANCE USING EXPONENTIALS, by P. Cormac; 151 pages, size 5½ by 8½ in., cloth; New York, 1923. Price $8.00.

"Using exponentials" seems to be the key note of this work for they are certainly used liberally. It is nothing short of an advanced course in exponential equations but it is a means to an end probably the shortest, most direct and possibly the only means to that end and should, therefore, be justified.

The book was written for engineers who are interested in exact engine balance and is, in reality, a text for specialists on engine design.

In the words of the author, "the introduction of exponentials not only permits of the ordinary engine balance topics being discussed with remarkable ease but it also enables one to examine, with little labor, the more complex types of aviation engines. In the design of crank systems, with specified balance, the exponential method gives elegantly, results of great importance.

"Attention may be called to the harmonic analysis of the motion of machine pieces by manipulation of the trigonometric expression through exponentials. The relations established among the coefficients in the harmonic expressions can be used with advantage in their computation."

Types of engines given this treatment include the simple symmetrical engine, radial and rotary engines and oscillating cylinder engines. Methods of design are given for both coplaner and non-planer crank systems with specified balance.

The condensed appendix gives the expansion of various functions in trigonometric series encountered in the text.

ELEMENTS OF ENGINEERING THERMODYNAMICS, by James A. Moyer, James P. Caulderwood and Audrey A. Potter; second edition, size 5¾ by 9 in., 223 pages, cloth; New York, 1923. Price $2.50.

Correctly to interpret the results of experiments on or experience with various kinds of heat engines of whatever nature requires a basic knowledge of the relation between that and mechanical (or electrical) work, i. e., thermodynamics. Because of the nature of this relation any comprehensive study of the subject must of necessity presuppose an adequate mathematical background. In any engineering course it rightfully should be included in about the fourth year of study, following for instance, an elementary course in the integral and differential calculus.

For those unfamiliar with the subject of thermodynamics it may be said that by means of calculations based on its principles it is possible to predict, for instance, the effect of increasing compression pressures of an internal combustion engine or the result of incomplete interstage cooling on the efficiency and capacity of an air compressor and to show what maximum efficiency is obtainable for any heat engines operating under any given set of conditions.

This treatise sets out to cover the subject comprehensively and therefore includes a considerable quantity of mathematical treatment. To anyone, however, who can content himself with passing over the mathematical deviations without taking the trouble to wade through step by step the meaning may be made sufficiently clear to insure a working knowledge of the principles involved.

The book is an extension of a previous work "Engineering Thermodynamics" by Moyer and Caulderwood incorporating such supplementary material as was thought necessary to make it sufficiently inclusive to meet institutional requirements. The new material includes the theory of the hot air engine and internal combustion engine cycles; the appendix contains logarithmic tables, and the properties of steam, ammonia, sulphur dioxide and carbon dioxide. The general subject matter is treated under the several topics; principles and definitions, properties of perfect gases, and vapors, cycles of heat engines using gas, and vapors entropy, flow of fluids and applications of thermodynamics to compressed air and refrigerating machinery.

CENTURY ELECTRIC CO., St. Louis, has just issued bulletin No. 36 describing the Century alternating and direct current fans and giving not only exterior views but cross sectional drawings.

BULLETIN 154 issued by the Foxboro Co., Inc., of Foxboro, Mass., describes the improved helical tube movement for recording and indicating instruments which the company has developed. This is a new principle which the bulletin claims overcomes many of the "necessary evils" of recorder instrument construction.

HEINE BOILER CO. of St. Louis, Mo., has issued an attractive bulletin, No. 54, describing its V-type bent tube boilers. This is the latest design of boiler that the company has produced and is built for pressures up to 325 lb. and in sizes from 250 to 3800 hp. The bulletin is well illustrated and describes not only the details of the boilers but also the process of manufacture.

CENTRIFUGAL BLOWERS and compressors, and their application in water gas, coke oven and general industrial plants, are treated of in a catalog issued by the De Laval Steam Turbine Co., of Trenton, N. J. The apparatus described includes single-stage and multistage blowers and compressors for pressures up to 125 lb. per sq. in. The illustrations show numerous machines as installed in water gas plants, coal gas plants, and coke ovens, also as used as boosters in city gas distribution. Besides the description of structural details, the publication contains chapters on blower and compressor characteristics and testing, together with a theoretical and practical treatment of the compression of gases and of the flow of gases through pipes and conduits.

FORTY PER CENT POWER WASTED, is the estimate of friction loss given in a booklet on Industrial Lubricating Facts issued by the Bassick Mfg. Co., 2676 Crawford Ave., Chicago. The booklet discusses causes which increase friction and how these may be removed by a forced pressure system, also how labor of caring for bearings may be reduced. Special cases of interest to power plant engineers are stoker bearings, pump bearings, conveyors, line shafting, engine rocker arms, cranes and industrial machinery. Cleanliness and saving in lubricant are other advantages explained. Details of the Alemite pressure lubricating apparatus and fittings are shown and the method given by which engineers can try out the system for solving difficult lubrication problems and for reducing labor and power loss. The booklet can be secured by writing to the Bassick Mfg. Co. at 2676 North Crawford Ave., Chicago, Ill.